State of California

THE RESOURCES AGENCY

Department of Water Resources

BULLETIN No. 164

TEHACHAPI CROSSING DESIGN STUDIES

Book IV

MAY 1965

HUGO FISHER
Administrator
The Resources Agency

EDMUND G. BROWN
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TEHACHAPI PUMPING PLANT

COMPARATIVE ANALYSIS OF LIFT CONCEPTS

PUMPS AND INTERFACE ELEMENTS

VOLUME IV

PROGRAM MANAGEMENT

April 1965

DANIEL, MANN, JOHNSON, & MENDENHALL
Engineering Division
Los Angeles

Associate Consultants
MOTOR-COLUMBUS
Baden/Switzerland

VOLUME IV - PROGRAM MANAGEMENT

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CHAPTER 1

ORGANIZATION AND BIOGRAPHICAL BACKGROUND

The management of a technical program as complex as the Tehachapi Pump study requires an intensive concentration of administrative and technical talents with direct experience in large, complex programs. This portion of the report presents the basic background possessed by DMJM, the project organization developed for this program, and the techniques by which DMJM uses the firm's background in supporting and managing this program.

The project team formulated by DMJM consists of the following:

1. Daniel, Mann, Johnson, & Mendenhall, Los Angeles, California - a firm of architectural and consulting engineers with experience in various public works and other highly technical programs for national, state, and local governments and other political entities.

2. Motor-Columbus, Baden, Switzerland - a firm of consulting engineers with experience in planning and the design of hydroplants for water supply systems, prime power generation, and pump-storage power generating schemes.

3. S. Logan Kerr, Philadelphia, Pennsylvania - a consulting engineer with experience in hydraulic transients, cavitation, systems operation, and systems analysis.

4. Professor A. H. Church, New York University - a widely recognized and highly respected consultant in the fields of mechanical vibration, centrifugal pumps, and blowers.

5. Professor L. J. Hooper, Alden Hydraulic Laboratory, Worchester Polytechnic Institute - the Director of a widely known and well equipped hydraulics laboratory and an internationally recognized authority in the field of testing hydraulic machinery and flow channels.

The individual consultants have been integrated with specialists from the Motor-Columbus staff and with engineers and scientists from Daniel, Mann, Johnson, & Mendenhall to provide a well-balanced team of technical talents available for the performance of this program. In addition, DMJM is

prepared to supplement the basic project staff when required by the many and varied demands which arise during performance of the program.

In the following pages, a discussion of the various engineers and scientists assigned to the program and the mode of operation of the project staff is presented.

A. DANIEL, MANN, JOHNSON, & MENDENHALL

Daniel, Mann, Johnson, & Mendenhall is a California corporation which provides professional services in the planning, architecture, engineering, and systems fields on an international scale. DMJM ranks among the largest firms of its type, and consequently, has been able to assume the responsibility of successfully performing large, complex programs.

The managerial concept adopted by DMJM for this program is to provide an integrated and well-balanced project staff on a full-time basis to perform the fundamental requirements of the program. This project staff has been assigned within the DMJM organization as a team to concentrate exclusively on the Tehachapi Pump program.

The project team has been supplemented as required through the utilization of various specialists in the engineering fields. These personnel are assigned to the program when their respective talents are required. By utilizing the project team approach with an experienced core of personnel participating on a full-time basis on the program, with other DMJM staff members available to add as support when their specific areas are required, DMJM has been able to meet the varying workloads and provide varying types of manpower with the specific experience required for this program.

The background of Daniel, Mann, Johnson, & Mendenhall in providing design and consulting services in engineering fields for numerous public works programs has been found to be extremely well suited to the demands and requirements of the Tehachapi Pump Research and Development Program. In addition to their depth and breadth of experience in civil engineering, DMJM has brought to bear a systems engineering capacity in the advanced sciences associated with project control, analysis of experimental data, reliability studies, and instrumentation and control systems.

The project staff at Daniel, Mann, Johnson, & Mendenhall is comprised of the following:

- <u>Project Director</u> - David R. Miller
- <u>Project Engineer</u> - Hans Gartmann
- <u>Project Staff</u> - G. E. Benz
  R. D. Bowerman
  R. W. Burge
  E. C. Cole
  R. A. Hall
  O. Hartmann, Motor-Columbus
  R. E. Westman
- <u>Support Staff</u> - W. W. Attrill
  G. Bachlund
  W. A. Dela Barre
  W. E. Grigsby
  B. E. Ibanez
  J. L. Kuebelbeck
  J. D. Reiter
  D. Woods

The entire staff of DMJM personnel participating in the Tehachapi Pump program, as shown above, is well qualified and highly respected as engineers and scientists.

Mr. David R. Miller is responsible for the administrative coordination of the program. In addition, he acts as secretary to the Technical Advisory Board.

Mr. Hans Gartmann, DMJM Project Engineer, received a Bachelor of Science Degree in Mechanical Engineering from Winterthur College in Switzerland. He is a registered Professional Engineer in the State of New Jersey and is a member of the American Society of Mechanical Engineers, Society of Naval Architects and Marine Engineers, and the American Society of Naval Engineers.

Mr. Gartmann is widely known in the field of hydraulic machinery and is currently a member (formerly chairman) of the Committee on Pumping Machinery of the ASME. For the past 20 years, he has been active on the various committees of the Hydraulic Institute and was chairman of the Centrifugal Pump Technical Committee in 1954-1956.

Prior to joining DMJM, Mr. Gartmann was a staff consultant and chief engineer of the De Laval Company and in complete charge of the engineering department and responsible for centrifugal pump design and development. He has supervised various technical studies including model development and testing, interpretation of laboratory research and development studies, the development of multistage centrifugal compressors, a line of 5500 PSI boiler feed pumps, stock pumps, liquor pumps, process pumps, and natural gas pipeline compressors.

B. MOTOR-COLUMBUS, LTD.

Motor-Columbus, Ltd. is an internationally known firm of engineers and consultants in all aspects of hydro work. Motor-Columbus was originally formed to provide services of a financial and promotional nature in connection with electrical supply. Subsequently, Motor-Columbus has developed a notable group in the production, distribution, and utilization of hydro and electrical energy. During the course of attaining its position in this field, Motor-Columbus has acquired an extensive background in mechanical engineering, particularly in the areas of pumps, turbines, valves, and auxiliary equipment. In addition, Motor-Columbus has experience in electrical motors and in the hydraulic channels (or tunnels) leading to and from pump and turbine stations.

Within its present scope of activities, Motor-Columbus plans, designs, and supervises construction of major hydro plants throughout Europe, Asia, Africa and South America. During the span of years Motor-Columbus has participated in these programs, the firm has become recognized as a leader in the field.

The breadth of experience possessed by Motor-Columbus has provided an important capability to the team performing research and development studies for the development of the design and specifications for the prototype Tehachapi pump. More specifically, Motor-Columbus brings a first hand knowledge of European pumping and technical practices to the program.

One of the major personnel contributions of Motor-Columbus to this program is Mr. Peter Jaray. Mr. Jaray is a member of the Technical Advisory Board of the Tehachapi Pump Program.

Mr. Jaray is Vice-Director and Chief Engineer at Motor-Columbus. Since receiving his M.S. degree in Electrical Engineering from the Swiss Federal Institute of Technology at Zurich, Mr. Jaray has become especially

skilled in the management and administration of the design of large pumping schemes. He is a member of the Swiss Engineers and Architects Society, Committee on Hydraulic and Electrical Machines as well as being associated with the Swiss Electrotechnical Society.

Mr. Jaray was associated with design and installation of mechanical equipment for the Tremola, Dobsina, Peccia, Zervreila, Ferrera and Ova Spin storage pumping plants. As special consultant he was also responsible for control techniques applied to the KNT and KSR Pumping Plants of the Jordan Project in Israel.

Among Mr. Jaray's contributions to the technical literature of his profession are "The Mechanical Equipment of Ferrera Underground Power Station" and "Study of Special Problems of the Electro-Mechanical Equipment of Power Stations".

Mr. Otto Hartmann is a Senior Design Engineer and Project Engineer for the Tehachapi Program for Motor-Columbus. He was awarded an M. S. in Mechanical Engineering from the Institute of Technology, Vienna, Austria and has specialized experience with the design of hydraulic equipment, tool machinery and precision calibration equipment. During the past seven years his work has included particular emphasis on hydraulic turbines, storage pumps and governors.

Mr. Hartmann co-authored a paper entitled "The Present State of Pumped Storage in Europe", which was presented at the 1962 Winter General Meeting of the American Institute of Electrical Engineers. He is fluent with both German and English and is serving in a technical liaison capacity during the model testing and pumping plant surveys.

C. TECHNICAL ADVISORY BOARD

In the performance of projects similar to the Tehachapi Pump research and development program, DMJM has found the counsel of a Technical Advisory Board to be invaluable. Such a group is formed from senior management and technical personnel from within DMJM, from associate organizations, or retained on a consulting basis. The Technical Advisory Board is responsible for appraisal of documents, attendance of inhouse briefings, and providing project guidance. Technical Advisory Board members are privileged to question all project personnel and to evaluate the correctness of approach and quality of performance of a project. In many cases, the Technical Advisory Board leads the reconcentration of activities when required on a program.

The Technical Advisory Board for the Tehachapi Pump Program consists of the following Personnel:

1. I. F. Mendenhall - President of Daniel, Mann, Johnson, & Mendenhall and a widely recognized civil engineer with experience in planning, consulting, and design of many important engineering and public works projects.

2. John T. Clabby, Vice President of DMJM and Manager of Systems Engineering Division, with extensive experience in systems engineering, systems operations, and system management.

3. Peter Jaray - Vice President and Chief Engineer of Motor-Columbus with broad experience in high head pumping and hydro installations.

4. S. Logan Kerr - Consultant.

5. Leslie J. Hooper - Professor, Hydraulics.

6. Austin H. Church - Professor, Mechanical Engineering

7. David R. Miller - Secretary of Technical Advisory Board, and DMJM Project Director.

The Technical Advisory Board has convened on three occasions; September 9, 10, and 11, 1963, February 17, 18, and 19, 1964, and March 29, 30, and 31, 1965. In addition to the Advisory Board members, several visiting engineers and administrators have been present at all meetings. For example, the Tehachapi Crossing Consultant Board formed by the State Department of Water Resources has asked J. Parmakian to attend the DMJM Technical Advisory Board meetings as a liaison. Mr. Parmakian is a former director at the U. S. Bureau of Reclamation where he specialized in the solution of hydraulics problems. Among his papers is "Pressure Surges at Large Pump Installations", ASME Transactions, 1963.

The TAB meetings held to date have been open meetings and DMJM staff members have attended as required and when possible as a matter of interest. A typical session of the Advisory Board is comprised of the following:

1. A briefing report summarizing recent accomplishments within the scope of the program is prepared and presented to each member of the Technical Advisory Board for review, approximately two weeks in advance of Board meeting date.

2. An agenda is prepared by the Secretary of the Technical Advisory Board.

3. The first Board meeting is a closed meeting to Board members only at which time the Board is briefed on the agenda and the intent of this specific meeting.

4. At a series of general opening meetings, DMJM staff members or other qualified personnel present briefings to the Board to summarize recent findings, to more clearly present to all Board members the scope of the program at that point, and to answer questions raised.

5. With the assistance of DMJM staff members, and visiting engineers and administrators, the Technical Advisory Board formulates conclusive material regarding the performance of the program.

Mr. Irvan F. Mendenhall is chairman of the Technical Advisory Board, and responsible for conducting all meetings.

Mr. Mendenhall is President of Daniel, Mann, Johnson, & Mendenhall, and has been a member of various consulting and technical society boards and committees, such as the Board of Consultants to the City of Los Angeles in connection with the $47 million Hyperion Sewerage Program, and as a consultant on the $80 million Rihand Dam in India. He has also directed engineering surveys, studies, and design of complex sewerage, power, and water enterprises in Europe, the Far East, South America, and Africa.

Mr. John T. Clabby is responsible for the technical and administrative operations of the Systems Division at Daniel, Mann, Johnson, & Mendenhall. The scope of his responsibilities encompasses management planning, design guidance, budgeting, cost estimating, and technical supervision. In this capacity he is currently responsible for direction of the design effort on the advanced control system configuration for the South Bay Aqueduct, a system which will provide the pilot model for the Feather River Project. This undertaking is of particular significance to the Tehachapi installation.

D. SPECIAL CONSULTANTS

To assure utmost integrity in the final results of this program, DMJM has retained several consultants of international stature for participation in the program. These engineers and scientists are available on a call basis and participate in programs to the extent demanded by the specific problems.

The consultants currently utilized as a part of this program are S. Logan Kerr, Professor L. J. Hooper, and Professor Austin H. Church.

Mr. S. Logan Kerr is internationally known for his contribution to hydraulics and respected as an authority in fields of water hammer, surges, and hydraulic transients. He has prepared numerous technical articles and has participated in preparation of several handbooks on hydraulics. In addition, he has been a member and has been chairman of several national committees of the ASME and holds patents in the fields of surge control valves, pump check and regulating valves, and hydraulic turbine governors.

Mr. Kerr's early contributions in the field of hydraulics were in laboratory research, field tests, trouble shooting, and turbine design. He participated in the selection of parts and the design of hydraulic turbines for a major power development program. He directed several investigative programs in water hammer and in cavitation.

Mr. Kerr's most recent experience has been in the field of consulting. In the course of this work, he has participated in corrosion studies, cavitation investigations, selection of hydropower electric station equipment and has participated in several major pumping programs. For example, he has assisted in the design and implementation on a consulting basis of the (1) Owens River Hydroelectric plants for the Department of Water and Power, City of Los Angeles, California. (2) Diesel engine driven standby pumping units for the Bureau of Sewers, Baltimore, Maryland. (3) Pumping Stations, pipelines and pump storage projects for the Department of Water Resources, State of New Jersey Legislative Committee. (4) Hydraulic problems, pumping stations, control valve design, and 100 miles of steel lines for the Trans-Arabian Pipeline. (5) A 75 mgd capacity, 40 mile pipeline and two pumping plants for the City of Birmingham, Alabama. (6) Hydraulic and surge studies for 150 miles of pipeline with pumping stations for the Mekaroth Water Company, Tel Aviv, Israel. (7) Hydraulic Surge operating studies for the City of Philadelphia Water Department. (8) Investigation of Operations and Repairs for the Aduccion Tuy-Mariposa Pipeline and Pumping Stations, Caracas, Venezuela. (9) Surge analysis for Penstocks, Coteau Creek Project, Saskatchewan Power Corporation. (10) Hydraulic and surge studies for pumping stations with 55 miles of pipeline, Flint, Michigan. (11) Hydraulic and surge studies on 400 mgd plant, State of New Jersey. (12) Surge studies and hydraulic analysis White River Municipal Water District, Fort Worth, Texas.

Another consultant employed by Daniel, Mann, Johnson, & Mendenhall to assist in the preparation of design specifications for the pump for installation by the California Department of Water Resources at the Tehachapi Crossing

is particularly noted for his contributions in the field of vibrations and centrifugal pumps. This consultant, Austin H. Church, is currently visiting professor of mechanical engineering at Duke University, on leave of absence from New York University. Professor Church's background has been gained through his long associations with Westinghouse, De Laval, General Electric, and various educational institutions. With De Laval Steam Turbine Company, Professor Church participated in the solution of special problems in centrifugal compressors, pumps, governers, vibrations, turbines and gears. He assisted Mr. H. Gartmann in the editing of the De Laval Engineering Handbook in 1947 and in 1954. With the General Engineering Laboratory of General Electric Company, Professor Church assisted in the solution of special problems on vibrations and in stress analyses. In addition, Professor Church has held many consulting assignments in centrifugal pumps and compressors and particularly in the problems of vibration on rotating machinery with organizations such as IBM, M. W. Kellogg, Chandler-Evans Corporation, Elliott Company, and Fluid and Electro Devices Incorporated.

Professor Church has held positions with Cooper Union College, New York University and Duke University. While at New York University, Professor Church authored the following texts:

1. Centrifugal Pumps and Blowers, 1944.

2. Kinematics of Machines, 1948.

3. Mechanical Vibrations, 1957 and 1953.

In addition to these texts he has prepared several papers and articles for publication in the journals of nationally recognized engineering associations.

Another member of the Technical Advisory Board is Professor Leslie J. Hooper who is director of the Alden Hydraulic Laboratory at Worchester Polytechnic Institute. Mr. Hooper was appointed professor of hydraulics engineering in 1945 after serving as an instructor for a period of 15 years. He became head of the Alden Hydraulic Laboratory at Worchester Polytechnic Institute in 1950 and has been responsible for the continued growth of the laboratory and the expansion of the test programs over the subsequent years.

Professor Hooper is particularly noted for his work in the salt velocity method of measuring the flow of water and in the sponsoring of basic research programs by various graduate level students.

The Alden Hydraulic Laboratory is recognized as one of the leading laboratories for the studies of hydraulics and fluid flow. Projects undertaken in these laboratories have pioneered in the design of water wheels, turbines, dams, spillways, river flow characteristics, and other projects. Although a primary purpose of any laboratory is to provide calibration facilities for industrial products, the Alden Laboratory has, in addition, participated in research on bombs and missiles as they enter a water atmosphere, calibration studies utilizing magnetic flow meters, and smoke dissapitation studies.

Professor Clifford Proctor Kittridge has been utilized by DMJM as a consultant in the analysis of pump efficiencies and step-up techniques. The results of these studies have been formalized and have been presented in progress report form to the California Department of Water Resources.

Professor Kittridge is currently a staff member of the School of Engineering and Applied Sciences at Princeton University. In this capacity he has instructed in statics, dynamics, mechanics of materials, thermodynamics, and fluid mechanics to undergraduate students and in fluid mechanics to graduate students. In addition to his duties as an instructor in engineering, Professor Kittridge has provided consulting services to De Laval Steam Turbine Company, Colvulc Rubber Company, U. S. Army Engineers, Kody Blower Corporation, All-American Engineering Company, Ingersol-Rand Company, Integral Pump Corporation, and Arthur D. Little, Incorporated. In various capacities with these organizations, he has participated in water hammer studies, the design of high specific speed pumps, heat transfer, metering of chilled deionized water, the use of rubber coatings to protect metals from cavitation, water supplies for air bases, high friction and noise reduction studies, tests on axial fans, tests on pumps, and the preliminary design of a high pressure submarine test facility.

It is the intent of DMJM to continue to use the services of these specialists and to add other consultants when required.

E. MODEL TEST FIRMS

Daniel, Mann, Johnson, & Mendenhall surveyed the entire pumping machinery field and reviewed proposals from the following outstanding organizations:

• Allis-Chalmers	USA
• Baldwin-Lima-Hamilton	USA
• Byron Jackson	USA
• Hydraulic Institute	Switzerland
• Newport News	USA
• Foster Wheeler	USA
• Dominion Engineering	Canada
• National Engineering Laboratory	Scotland
• Bergeron	France
• Riva	Italy
• Sulzer Bros.	Switzerland
• J. M. Voith	Germany
• Escher-Wyss	Switzerland
• Hitachi	Japan

Based on a careful analysis of the capabilities, specific proposals were solicited from:

- Allis-Chalmers/Sulzer Bros.
- Baldwin-Lima-Hamilton/J. M. Voith
- Newport News/Escher Wyss
- Byron Jackson

These proposals were exhaustively evaluated for their specific capabilities in testing, past experience, manufacturing, management, personnel, and project approach. This evaluation led to the selection of specific firms for performance of programs to provide data on pumps suitable for use in one lift, two lift, and three lift pumping systems.

Daniel, Mann, Johnson, & Mendenhall then contracted for the services of three of these organizations to design, fabricate, and experimentally evaluate models of pumps associated with the three lift concepts under consideration for the Tehachapi Crossing. They are as follows:

. Single Lift Concept - Allis-Chalmers of Milwaukee, Wisconsin and Sulzer Bros. of Winterthur, Switzerland to investigate a four-stage, single-flow vertical pump model.

. Two Lift Concept - Baldwin-Lima-Hamilton of Philadelphia, Pennsylvania and J. M. Voith of Heidenheim, Germany to investigate a two-stage, double-flow vertical pump model.

. Three Lift Concept - Byron Jackson of Los Angeles, California, a division of Borg Warner, to investigate a single-stage, single-flow vertical pump model.

Each of these organizations were selected expressly for their specific capabilities in the types of pumps assigned for investigation. Each organization is considered to be most outstanding in the field of pumping machinery for which they have been retained.

The following portion of the report presents general data on each of these industrial organizations participating in this pump research program, and comments on the specific contributions each firm may make to the ultimate implementation of the Tehachapi Pumping Station are presented.

1. <u>Allis-Chalmers/Sulzer Bros.</u>

Allis Chalmers and Sulzer Bros. have jointly participated in several programs in the past and are expected to participate in the Tehachapi Pumping Plant program as follows:

a. Allis-Chalmers - leader of the research team and noted American manufacturer of large rotating hydro and electric machinery.

b. Sulzer Bros. - a manufacturer of large pumping machinery with excellent facilities for experimental work and a broad background in the design of hydraulic machines.

In this program, Sulzer Bros. will design the prototype pumps, and design, fabricate and test a scale model of this prototype.

Allis-Chalmers is an extremely large organization with broad capabilities in all forms of equipment dealing with moving fluids and hydroelectric stations.

Allis-Chalmers has 26 plants in the United States and abroad. Allis-Chalmers has over 4,000 machine tools at their West Allis works ranging to a 40-foot diameter boring mill. Other large fabrication equipments are available in other Allis-Chalmers plants. Allis-Chalmers employs several hydrodynamicists who are noted and recognized as leaders in their fields.

For over 80 years Allis-Chalmers has played an important role in the design and building of all types of hydraulic machines. Included in these programs are turbines, pumps, motors, generators, valves, and all associated and support equipment. Notable installations include Hoover Dam, Shasta, Nixon Rapids, Shipshaw, Chief Joseph, Fontana, Osage, Belmont, Saint Lawrence, Nimbus, Flat Iron, Hiwassee, Lewiston, Comstock, and Smith Mountain. The ability of Allis-Chalmers to design, fabricate and erect large hydraulic machinery is unique in the industry.

Sulzer Bros. of Winterthur, Switzerland was formed as a family enterprise in 1934 and became a limited liability company in 1914. Sulzer employs over 11,000 personnel in Switzerland and have affiliated companies throughout the world. Sulzer products include all heavy mechanical engineering equipment, such as diesel engines, locomotive engines, steam power plants, steam generators, heating and air conditioning plants, gas turbines, steam turbines, turbo compressors, piston compressors, high pressure pipelines, and textile machinery. 'Sulzer is particularly noted for their capabilities in the field of designing, fabricating, and installing large pumps and turbines utilized in the hydraulic field.

Sulzer possesses one of the finest privately owned pump test facilities in the world. This facility was built to perform all types of model and full-scale tests and is equipped with modern electric drives, dynamometers, and measurement devices.

The addition of Allis-Chalmers/Sulzer Bros. to the team of engineers and scientists who are contributing to the selection of the pumps for the Tehachapi Crossing will add a depth of capabilities which is considered absolutely necessary for the successful completion of this program.

2. <u>Baldwin-Lima-Hamilton/J. M. Voith GmbH</u>

The firms of Baldwin-Lima-Hamilton and J. M. Voith were selected to do the design and experimental program with the double flow, two-stage pump. Baldwin-Lima-Hamilton of Philadelphia, Pennsylvania has brought to this program a depth of capabilities in hydraulic design and fabrication and,

in addition, possesses the resources required for casting, machining and fabricating the machines required for the Tehachapi Crossing.

Baldwin-Lima-Hamilton has been engaged in manufacturing hydraulic equipment for over 100 years. The first turbine manufactured by Baldwin-Lima-Hamilton was installed in 1851 in the City of Philadelphia. Since that time, the firm has installed hydraulic units at Roos Dam in Seattle, Garrison Dam, Big Project, Niagara Power Project, Poe Power House, Bridge River, Hass, Old Hickory, the Dales Dam and many other locations.

Baldwin-Lima-Hamilton has grown to a company with several domestic and foreign divisions and subsidiaries. Their major products are hydraulic machinery, including pumps and turbines, ship propellers, water works, sewerage and power plant pumps and various equipment used in support of hydraulic installations. In addition, Baldwin-Lima-Hamilton produces electronic products, construction equipment, automotive components, fans, dust collectors, supervisory controls and marine equipment for a variety of users.

J. M. Voith of Heidenheim, Germany, is internationally noted for their capabilities in the design of hydraulic machinery. J. M. Voith was formed over 100 years ago in Germany to manufacture hydraulic machinery. A founder of the Voith organization is a noted hydrodynamicist and has been recognized as a major contributor to the development of early hydraulic machinery. The experience of Voith includes the construction of all types of turbine equipment, pumps, oil pressure speed governors, relief valves, automatic control equipment, synchronizing torque converters, hydraulic couplings, electrical distribution systems, gates, trash racks, and rack cleaning machines. In addition, J. M. Voith has participated in the manufacture of ship propulsion systems, railroad propulsion and air conditioning equipment, various types of heating and cooling radiators, centrifugal fans, axial fans, aerodynamic shapes for railroad cars, and electronic counters and meters.

Throughout the history of the organization, specific attention has been paid to the development of laboratories and laboratory equipment. At this time, J. M. Voith possesses a hydraulic facility with a 150-foot head and water flow rates sufficiently large to test models of high horsepower. In addition, Voith has propeller test facilities, cavitation test loops, calibration equipment, and equipment for testing several types of turbines.

By selecting a combination of Baldwin-Lima-Hamilton and J. M. Voith o participate in this program, this project will benefit from the extensive :xperience in the design, fabrication, and installation of pumping machinery .nd be assured of a complete capacity and capability to produce and install arge machinery.

3. <u>Byron Jackson</u>

The Byron Jackson Company, a Division of Borg-Warner was selected or the performance of the design and research program related to single-tage pumping systems utilized in the three lift concept. Byron Jackson was ormed in 1872 and has subsequently been recognized as a leader in the design, abrication and installation of hydraulic machinery. Byron Jackson was ormed primarily to manufacture pumps for use in the mining and irrigation ndustries. Subsequently, Byron Jackson has entered the petroleum, electro-ics, and civil engineering fields for many programs. Byron Jackson has esigned pumps for boiler feed systems, nuclear and radioactive fluid handling ystems, pipeline pumps, deep well pumps, and many systems related to the novement of large quantities of water.

The Byron Jackson Company will provide the model testing required demonstrate the feasibility of utilizing a three lift pumping concept mploying large single stage pumps for the Tehachapi Crossing.

CHAPTER 2

MANAGEMENT CONTROL PROGRAM - PERT

A. SUMMARY

The principal objective of DMJM in the design and implementation of PERT was to provide a control system capable of making a significant contribution to the management of the CALPUMP program. It was found that PERT would be a significant aid in performing the following management functions for the Tehachapi Pump Program:

- planning
- scheduling
- progress reporting
- review

In addition, elements and results of the DMJM PERT system may be used by the Department of Water Resources to assure compliance of the pump program with the entire California Water distribution system.

DMJM established the PERT program and incorporated the requirements in the model pump test firm contracts. Subsequently, periodic reports compatible with DMJM requirements have been reviewed from each firm.

In this chapter the PERT control techniques being used by DMJM in the management of the Tehachapi Pumping Plant, Research and Development Program are discussed. Following the introductory discussion, detailed status reports of the overall program and of the three model test firm programs are presented for the latest PERT reporting period.

B. INTRODUCTION

1. General

PERT was developed in 1957 by a joint research team comprised of elements from the U. S. Navy Special Projects Office for use on the

Polaris Weapon System Program. PERT was not designed to replace, but to supplement management tools such as bar charts, milestone charts, and line of balance techniques. PERT is based on the principles of operations research and utilizes detailed preplanning for each project. PERT provides for a management-by-exception system by placing emphasis upon the "pacing" or "critical" items of a project. Operations re search analyses of previous complex programs have revealed that only 10 to 20 per cent of the activities in a project control the time required to complete the project. The principal analytical tool of PERT is the "critical path" which points out these pacing activities. Delay or acceleration of performance of these activities will directly affect the completion date of the project.

2. Value of PERT in a Project of this Nature

Basically, all projects must start with a planning phase. Planning is most effectively performed and achieves the greatest benefit if performed by management with subsequent detail plans expanded by technical groups within this structure. PERT facilitates this type of planning in a project since all activities are logically arranged. Management may, through the use of a summary PERT network, define the intermediate and final objectives of a program and then outline the major element functions and activities which will constitute the program and assure inclusion of all requirements. The network technique assures that vital interdependencies between critical elements of the program are clearly defined. Individuals from sponsoring, engineering, and contracting organizations can readily and clearly identify and communicate the specific relationships of their efforts to the total project by means of a valid and well described network. PERT explicitly reveals interdependency and potential schedule problems which would remain undefined by former planning methods. It would be extremely difficult to evaluate the impact upon other program activities and/or the project completion date of a change in duration or slippage of an activity in a project which used only bar charts for program control. Thus, if interfaces are properly depicted between the contractor and DMJM's study network, the individual plans and their associated schedules will be joined into one overall cohesive plan of action for the entire program.

After the plan has been developed PERT provides additional aid to the planning team by allowing an evaluation of the resulting schedule to be made and by highlighting those areas which must be altered to improve the schedule within specified objectives. The results of efforts to improve the schedule will be immediately apparent and the effect upon related activities in the program can be immediately discerned. Alternate plans and/or

management policies may be simulated to rapidly determine their probable success and effects. Thus, assurance is gained in that the optimum plan for the circumstances of resource availability and schedule constraints will be placed in effect. PERT is a powerful management aid in that it is a multipurpose tool. Thus, PERT also serves as a reporting vehicle of the status of work.

Periodic status reports enable a customer to determine:

- the status of important events and thus the progress of the project,

- an accurate projection of future status, i.e., the expected completion dates of intermediate and final objectives in comparison with current plans and schedules,

- critical and noncritical activities ranked in order of their effect on the schedule,

- the problem areas requiring management intervention and,

- the probable effects of plans conceived to recover lost time.

The major elements of the PERT system are:

- the operating and technical units, that is, the model test firms and the DMJM research staff which provide the raw data to the system,

- the reporting system which is a standardized vehicle for communications of data,

- the PERT staff which analyzes the PERT data and provides the output information, and

- DMJM management whose judgement and experience results in control decisions which may be communicated through the PERT channel as guidance or direction to the operating units.

The wealth of detail produced by PERT allows management to evaluate the progress of work with a greater degree of precision than formerly possible. However, management's desire to manage by exception

as a means of making the most of limited time is not served by a mass of detail. Thus, analyses are made to discern the current trend or outlook and to highlight problem areas requiring management attention. The typical product of a PERT analysis is a discussion of current trends and of problem areas where improvement in performance or a revised plan are required. This discussion is normally supported by the current status of the number of days ahead or behind schedule with respect to target objectives. These data indicate past performance and establish the trend in future performance. Other data indicate the target schedule for intermediate milestones relative to the currently projected dates. These data also show the actual completion dates of events which have occurred in the past which in conjunction with the projected schedule serve to confirm the trends. Thus, management is not only advised of the current status of work in progress but is also given precise planning dates for future milestones and an indication of the effects of expected dates assigned to these milestones. Further, the detailed schedule contained in the computer output is forwarded along with the analysis to the model test firm or research team for guidance in planning their work. Management direction to alter the pace of progress or to revise program plans are nonroutine communications and are transmitted by other channels.

C. STATUS REPORTS

Nine sub-networks were developed which, taken together, describe the scope of the total effort required in this program. Each of the model test firms has a sub-network describing its activities; the remaining six networks describe the following special studies being performed by DMJM in house: (1) the pump research study network, (2) the motor study network, (3) the valve study network, (4) the hydraulic transients study network, (5) the reliability study network, and (6) the wear test program network.

The total network developed at the beginning of the project contained over 1200 activities. Since that time, many activities have been completed and the network activity count has diminished to 825. The description of the model test firm programs require 420 separate activities.

The model test firms, through the medium of a standardized reporting system, report the status of the activities within the program once every half month. Standard forms have been developed and are made available to the operating units for ease of reporting. The information to be reported falls into the following categories:

- Activities which have been completed during the preceding report period.

- Activities which are in progress.

- Activities which are expected to start during the forthcoming report period.

- Deletions, additions, or revisions to the network.

1. Integrated Programs

For overall project control, DMJM has developed an integrated network of all scheduled activities. This network is updated periodically and is used to relate the nine sub-networks. The integrated network as of December 31, 1964, includes the following subprograms.

1. AC/Sulzer Model Pump Program
2. BLH/Voith Model Pump Program
3. Byron Jackson Model Pump Program
4. Pump Research Study
5. Motor Study
6. Valve Study
7. Hydraulic Transients Study
8. Reliability Study
9. Wear Test Program

The Integrated PERT Diagram is presented in Figure 2-1. The data noted in this diagram were analyzed by computer techniques and a summary of the major results are presented in Table 2-I. These results reflect program status as of December 31, 1964.

Table 2-I shows the current status of major events with respect to target schedule dates. Schedule dates for "receipt of revised model test firm proposals" and "notices to proceed issued" were taken from the April 29, 1964 DMJM Program Approach letter. Target schedule dates for model test firm events were determined from each firm's planned sequence of activities and from activity time durations given in the DMJM/Allis Chalmers, DMJM/Baldwin Lima Hamilton, and DMJM/Byron Jackson contracts.

The scheduled date for completion of the DMJM Preliminary Report has been changed to February 24, 1965. This slippage coincides

Activity No.	Description	Date Completed	Scheduled Completion Date	Calendar Days	
				Ahead	Behind
	Work Commenced	7-15-63			
	Revised Model Test Proposals Received				
	AC/Sulzer	4-23-64	4-20-64		3
	BLH/Voith	4-20-64	4-20-64		
	Byron Jackson	4-24-64	4-20-64		4
	DWR Approval of Model Test Contracts				
	AC/Sulzer	6-11-64			
	BLH/Voith	6-12-64			
	Byron Jackson	6-1-64			
	Contract Modification Accepted by Firms				
	Allis-Chalmers	6-26-64			
	Baldwin-Lima-Hamilton	6-19-64			
	Byron Jackson	6-19-64			
	Notices to Proceed Issued				
2-3	Allis-Chalmers	6-29-64	5-20-64		40
113-114	Baldwin-Lima-Hamilton	6-23-64	5-20-64		34
276-277	Byron Jackson	6-23-64	5-20-64		34
	Model Test Firm Work Commenced				
3-4	AC/Sulzer	7-9-64	7-9-64		
114-115	BLH/Voith	7-3-64	7-3-64		
277-278	Byron Jackson	7-3-64	7-3-64		
	Review of Model Design				
8-11	AC/Sulzer (4-stage, single flow model)	9-31-64	9-31-64		
150-155	BLH/Voith (2-stage, double flow model)	9-31-64	9-31-64		
285-287	Byron Jackson (1-stage, single flow model)	9-31-64	9-31-64		

TABLE 2-I INTEGRATED PROGRAM EVENTS STATUS

as of December 31, 1964

Activity No.	Description	Expected Completion Date	Scheduled Completion Date	Calendar Days	
				Ahead	Behind
41-42	Preliminary Information on Efficiency				
41-42	AC/Sulzer (Pump Model #1 Tests)	3-26-65	4-20-65	25	
211-212	BLH/Voith (Final 1-Stage H-Q-E Tests)	1-21-65	1-19-65		2
322-323	Byron Jackson (First Preliminary Tests)	1-29-65	12-7-64		53
507-508	DMJM Preliminary Report	3-9-65	2-24-65		13
	Final Information on Efficiency				
44-46	AC/Sulzer (4-stage, single flow model)	4-20-65	5-5-65	15	
225-226	BLH/Voith (2-stage, double flow model)	5-19-65	7-13-65	55	
338-340	Byron Jackson (1-stage, single flow model)	3-15-65	3-5-65		10
	Model Test Firm Preliminary Reports Received				
59-78	AC/Sulzer	7-28-65	7-14-65		14
243-245	BLH/Voith	8-9-65	9-1-65	23	
399-402	Byron Jackson	4-28-65	5-25-65	27	
	Complete Testing				
98-100	AC/Sulzer	9-10-65	9-2-65		8
262-263	BLH/Voith	10-15-65	10-6-65		9
431-433	Byron Jackson	8-10-65	7-14-65		27
	MTF Final Report Drafts Received				
871-879	AC/Sulzer	12-8-65	12-31-65	23	
269-271	BLH/Voith	12-16-65	11-2-65		44
438-441	Byron Jackson	9-29-65	12-27-65	89	
865-866	DMJM Research Report Draft Complete	2-18-66	1-31-66		18
868-869	DMJM Final Report to Printer	4-6-66	4-29-66	23	
869-870	All Work Completed	5-11-66	5-30-66	19	

TABLE 2-I (Continued) INTEGRATED PROGRAM EVENTS STATUS

as of December 31, 1964

The Tehachapi Pumping Plant PERT diagrams (Figure 2-1) are available in the library of the Resources Agency.

with the last model test firm notice to proceed being issued on June 29, 1964 instead of May 20, 1964.

The scheduled date of May 30, 1966 for "all work completed" has not changed and is in accordance with the DWR/DMJM contract.

The Integrated PERT Program has been continually monitored by DMJM managerial and technical personnel and all changes in scheduled events have been noted and reported as required.

2. <u>Model Test Firm Status Reports</u>

Individual model test firm schedules are updated semimonthly, based on data received from each firm. The results of these updating procedures are integrated into the overall PERT diagram.

Each PERT Status report contains the following:

(a) An analysis of current status

(b) Updating of PERT networks

(c) A table of important events status showing completed activities and changes in forthcoming activities.

(d) A curve showing the deviation of expected receipt of final report draft as a function of program elapsed time

(e) Computer schedule listing

(f) PERT diagram

Copies of current PERT Status Reports for the three model test firms are included as follows:

(a) Byron Jackson Model Pump Program status as of February 15, 1965

(b) Baldwin Lima Hamilton/Voith Model Pump Program status as of February 15, 1965.

(c) Allis Chalmers/Sulzer Model Pump Program status as of February 15, 1965.

These status reports provide a summary of program progress at the time of issue of this report.

DMJM DANIEL, MANN, JOHNSON, & MENDENHALL
PLANNING § ARCHITECTURE § ENGINEERING § SYSTEMS

PERT STATUS REPORT NO. 8
BYRON JACKSON
As of: February 15, 1965
Distributed: March 2, 1965

PERT STATUS

BYRON JACKSON MODEL PUMP PROGRAM

Distribution
Department of Water Resources
Byron Jackson

Approved: Hans Gartmann
Hans Gartmann
Project Engineer

This report presents the current Byron Jackson Model Pump Program schedule derived from their PERT report for the period ending February 15, 1965.

The critical path has shifted from preliminary performance tests to component manufacture (319-311), test loop assembly (311-893), and calibration (894-895).

Test data from the preliminary tests is anticipated to be available as follows:

Pump Model Number	Tests Start	Tests Complete	Test Data Processed
1	In Progress	2-19-65	2-23-65
2	2-24-65	3- 1-65	3- 3-65
3	3- 4-65	3- 9-65	3-11-65
4	3-12-65	3-17-65	3-19-65

Activity No.	Description	Expected Early Start Date (ES)	Early Finish Date (EF)		Target Schedule Completion Date (TS)	TS-EF (working days)	
			Date Completed	Expected Completion Date		Days Ahead	Days Behind
311-893	Test Loop Assembly	3-4-65		3-16-65	11-25-64		74
319-320	Workshop Assembly of Model		2-11-65		11-25-64		56
322-323	First Preliminary Tests	In Progress		2-19-65	12-7-64		50
331-332	Last Preliminary Tests	3-12-65		3-17-65	1-29-65		33
338-340	Final H-Q-E Tests	3-31-65		4-8-65	3-5-65		24.17
358-360	Thrust Tests	4-30-65		4-30-65	3-31-65		22.49
374-376	Cavitation Tests	5-17-65		5-17-65	4-26-65		15.49
399-402	Receipt of Preliminary Report	5-24-65		5-24-65	5-25-65	0.01	
398-400	Complete 3-Quadrant Testing	7-26-65		7-26-65	6-24-65		21.98
431-433	Complete Testing	9-3-65		9-3-65	7-14-65		37.82
438-441	Receipt of Final Report Draft	10-4-65		10-24-65	12-27-65	40.85	

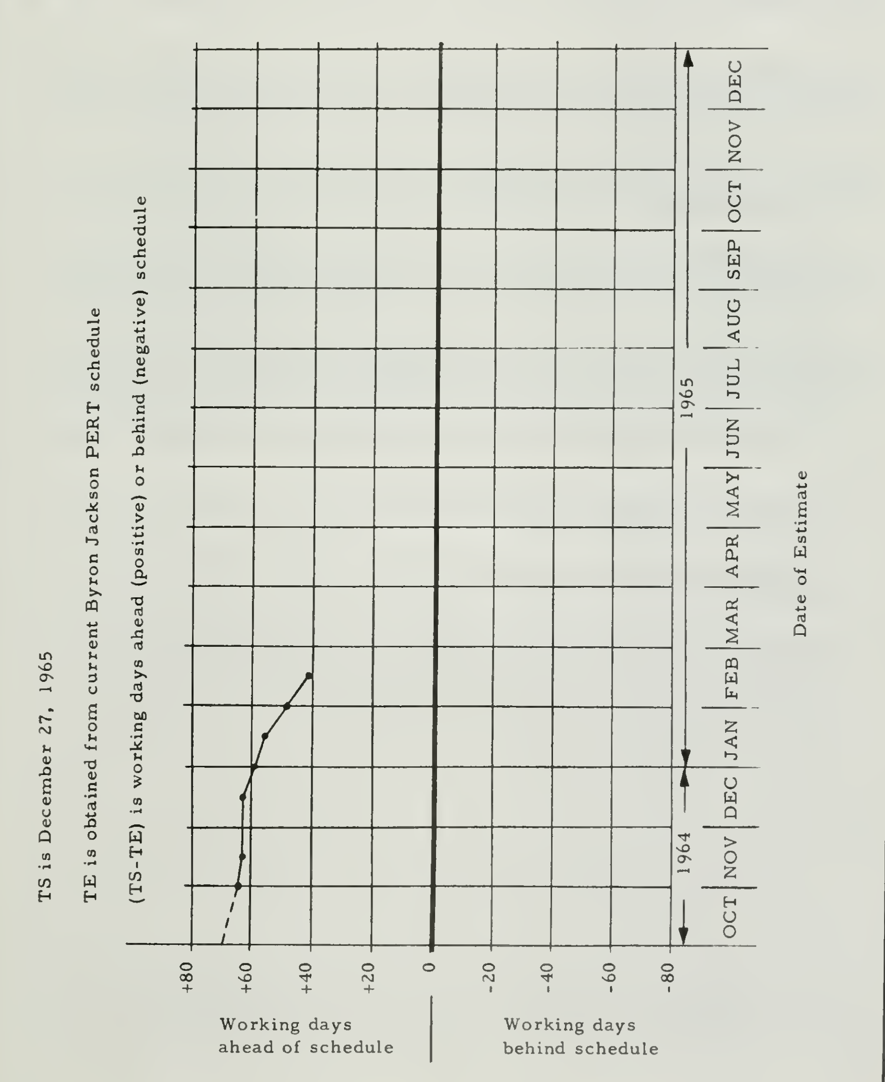
TABLE I. BYRON JACKSON IMPORTANT EVENTS STATUS

DMJM

DANIEL, MANN, JOHNSON, & MENDENHALL

PLANNING § ARCHITECTURE § ENGINEERING § SYSTEMS

Figure 1. Status of Expected Delivery Date of Byron Jackson Final Report Draft



S J PERT STATUS AS OF 15 FEB 65

START NODE	END NODE	MEAN TIME	OPT	MOST LIKELY	PESS	TS(EF)	PROB	VAR	TS-EF	EARLY START	EARLY FINISH	LATE START	LATE FINISH	TOTAL FLOAT	FREE FLOAT
322	323	3.00	2.00	3.00	4.00	02/19/65	.500	.11	.00	02/16/65	02/19/65	02/19/65	02/24/65	3.83	.00
* 322	311	12.00	10.00	12.00	14.00	03/04/65	.500	.44	.00	02/16/65	03/04/65	02/16/65	03/04/65	*	.00
322	337	15.00	10.00	15.00	20.00	03/09/65	.500	2.76	.00	02/16/65	03/09/65	03/22/65	04/12/65	24.82	.00
322	345	20.00	10.00	20.00	30.00	03/16/65	.500	11.09	.00	02/16/65	03/16/65	06/11/65	07/12/65	82.65	20.34
323	324	2.00	1.00	2.00	3.00	02/23/65	.500	.11	.00	02/19/65	02/23/65	02/24/65	02/26/65	3.83	.00
323	334	2.17	2.00	2.00	3.00	02/23/65	.500	.03	.00	02/19/65	02/23/65	03/23/65	03/25/65	22.00	18.17
324	325	1.17	1.00	1.00	2.00	02/24/65	.500	.03	.00	02/23/65	02/24/65	02/26/65	03/02/65	3.83	.00
325	326	3.00	2.00	3.00	4.00	03/01/65	.500	.11	.00	02/24/65	03/01/65	03/02/65	03/05/65	3.83	.00
326	327	2.33	2.00	2.00	4.00	03/03/65	.500	.11	.00	03/01/65	03/03/65	03/05/65	03/09/65	3.83	.00
326	334	2.17	2.00	2.00	3.00	03/03/65	.500	.03	.00	03/01/65	03/03/65	03/23/65	03/25/65	15.83	12.00
327	328	1.17	1.00	1.00	2.00	03/04/65	.500	.03	.00	03/03/65	03/04/65	03/09/65	03/10/65	3.83	.00
328	329	2.50	2.00	2.00	5.00	03/09/65	.500	.25	.00	03/04/65	03/09/65	03/10/65	03/15/65	3.83	.00
* 311	893	8.33	6.00	8.00	12.00	03/16/65	.500	1.00	.00	03/04/65	03/16/65	03/04/65	03/16/65	*	.00
337	339	.00	.00	.00	.00	03/09/65	.500	.00	.00	03/09/65	03/09/65	04/12/65	04/12/65	24.83	.00
329	330	2.33	2.00	2.00	4.00	03/11/65	.500	.11	.00	03/09/65	03/11/65	03/15/65	03/17/65	3.83	.00
329	334	2.17	2.00	2.00	3.00	03/11/65	.500	.03	.00	03/09/65	03/11/65	03/23/65	03/25/65	9.83	6.00
339	344	3.17	.00	3.00	7.00	03/12/65	.500	1.35	.00	03/09/65	03/12/65	04/12/65	04/16/65	24.83	.00
337	359	15.00	10.00	15.00	20.00	03/30/65	.500	2.76	.00	03/09/65	03/30/65	04/12/65	05/03/65	24.62	.00
330	331	1.17	1.00	1.00	2.00	03/12/65	.500	.03	.00	03/11/65	03/12/65	03/17/65	03/18/65	3.83	.00
344	346	.00	.00	.00	.00	03/12/65	.500	.00	.00	03/12/65	03/12/65	04/16/65	04/16/65	24.83	24.83
331	332	2.50	2.00	2.00	5.00	03/17/65	.500	.25	.00	03/12/65	03/17/65	03/18/65	03/23/65	3.83	.00
* 893	894	2.00	1.00	2.00	3.00	03/18/65	.500	.11	.00	03/16/65	03/18/65	03/16/65	03/18/65	*	.00
332	334	2.17	2.00	2.00	3.00	03/19/65	.500	.03	.00	03/17/65	03/19/65	03/23/65	03/25/65	3.83	.00
332	333	4.00	3.00	4.00	5.00	03/23/65	.500	.11	.00	03/17/65	03/23/65	03/23/65	03/29/65	4.33	.00
* 894	895	5.17	3.00	5.00	8.00	03/25/65	.500	.69	.00	03/18/65	03/25/65	03/18/65	03/25/65	*	.00
334	335	.00	.00	.00	.00	03/19/65	.500	.00	.00	03/19/65	03/19/65	03/25/65	03/25/65	3.83	.00
335	336	2.33	2.00	2.00	4.00	03/23/65	.500	.11	.00	03/19/65	03/23/65	03/25/65	03/29/65	3.83	3.83
333	336	.00	.00	.00	.00	03/23/65	.500	.00	.00	03/23/65	03/23/65	03/29/65	03/29/65	4.33	4.33
* 895	336	2.00	1.00	2.00	3.00	03/29/65	.500	.11	.00	03/25/65	03/29/65	03/25/65	03/29/65	*	.00
* 336	338	2.17	2.00	2.00	3.00	03/31/65	.500	.03	.00	03/29/65	03/31/65	03/29/65	03/31/65	*	.00
359	361	.00	.00	.00	.00	03/30/65	.500	.00	.00	03/30/65	03/30/65	05/03/65	05/03/65	24.98	.00
361	364	3.17	.00	3.00	7.00	04/02/65	.500	1.35	.00	03/30/65	04/02/65	05/03/65	05/07/65	24.98	.00
359	375	15.00	10.00	15.00	20.00	04/20/65	.500	2.76	.00	03/30/65	04/20/65	05/03/65	05/24/65	24.82	.00
* 338	340	5.50	3.00	5.00	10.00	03/05/65	.000	1.35	-24.17	03/31/65	04/08/65	03/31/65	04/08/65	*	.00
364	367	.00	.00	.00	.00	04/02/65	.500	.00	.00	04/02/65	04/02/65	05/07/65	05/07/65	24.98	24.98
340	341	3.17	2.00	3.00	5.00	04/13/65	.500	.25	.00	04/08/65	04/13/65	07/07/65	07/12/65	62.31	.00
* 340	343	3.33	2.00	3.00	6.00	04/13/65	.500	.44	.00	04/08/65	04/13/65	04/08/65	04/13/65	*	.00
340	342	4.00	3.00	4.00	5.00	04/14/65	.500	.11	.00	04/08/65	04/14/65	04/12/65	04/16/65	1.83	.00
341	345	.00	.00	.00	.00	04/13/65	.500	.00	.00	04/13/65	04/13/65	07/12/65	07/12/65	62.31	.00
* 343	346	2.50	2.00	2.00	5.00	04/16/65	.500	.25	.00	04/13/65	04/16/65	04/13/65	04/16/65	*	.00
345	368	5.00	4.00	5.00	6.00	04/20/65	.500	.11	.00	04/13/65	04/20/65	07/12/65	07/19/65	62.31	2.16
341	356	10.50	8.00	10.00	15.00	04/27/65	.500	1.35	.00	04/13/65	04/27/65	09/03/65	09/21/65	101.48	.00
342	346	.00	.00	.00	.00	04/14/65	.500	.00	.00	04/14/65	04/14/65	04/16/65	04/16/65	1.83	1.83
* 346	351	2.33	2.00	2.00	4.00	04/20/65	.500	.11	.00	04/16/65	04/20/65	04/16/65	04/20/65	*	.00
375	377	.00	.00	.00	.00	04/20/65	.500	.00	.00	04/20/65	04/20/65	05/24/65	05/24/65	24.82	.00
* 351	352	1.33	1.00	1.00	3.00	04/21/65	.500	.11	.00	04/20/65	04/21/65	04/20/65	04/21/65	*	.00
351	366	2.17	2.00	2.00	3.00	04/22/65	.500	.03	.00	04/20/65	04/22/65	07/15/65	07/19/65	60.15	.00
377	380	6.00	.00	6.00	12.00	04/28/65	.500	4.00	.00	04/20/65	04/28/65	05/24/65	06/02/65	24.62	.00
375	401	11.17	8.00	11.00	15.00	05/05/65	.500	1.35	.00	04/20/65	05/05/65	07/13/65	07/28/65	58.82	.00
* 352	353	1.33	1.00	1.00	3.00	04/22/65	.500	.11	.00	04/21/65	04/22/65	04/21/65	04/22/65	*	.00

B J PERT STATUS AS OF 15 FEB 65

	START NODE	END NODE	MEAN TIME	OPT	MOST LIKELY	PESS	TS(EF)	PROB	VAR	TS-EF	EARLY START	EARLY FINISH	LATE START	LATE FINISH	TOTAL FLOAT	FREE FLOAT
	366	368	.00	.00	.00	.00	04/22/65	.500	.00	.00	04/22/65	04/22/65	07/19/65	07/19/65	60.15	.00
*	353	354	2.33	2.00	2.00	4.00	04/27/65	.500	.11	.00	04/22/65	04/27/65	04/22/65	04/27/65	*	.00
	368	373	6.00	5.00	6.00	7.00	04/30/65	.500	.11	.00	04/22/65	04/30/65	07/19/65	07/27/65	60.15	2.16
	366	393	10.50	8.00	10.00	15.00	05/07/65	.500	1.35	.00	04/22/65	05/07/65	09/03/65	09/21/65	94.32	.00
	356	399	.00	.00	.00	.00	04/27/65	.500	.00	.00	04/27/65	04/27/65	09/21/65	09/21/65	101.48	19.15
*	354	355	1.17	1.00	1.00	2.00	04/28/65	.500	.03	.00	04/27/65	04/28/65	04/27/65	04/28/65	*	.00
*	355	357	.00	.00	.00	.00	04/28/65	.500	.00	.00	04/28/65	04/28/65	04/28/65	04/28/65	*	.00
	380	381	.00	.00	.00	.00	04/28/65	.500	.00	.00	04/28/65	04/28/65	06/02/65	06/02/65	24.82	24.82
*	357	358	2.00	.00	2.00	4.00	04/30/65	.500	.44	.00	04/28/65	04/30/65	04/28/65	04/30/65	*	.00
*	358	360	.00	.00	.00	.00	03/31/65	.000	.00	-22.49	04/30/65	04/30/65	04/30/65	04/30/65	*	.00
	360	371	2.17	2.00	2.00	3.00	05/04/65	.500	.03	.00	04/30/65	05/04/65	07/23/65	07/27/65	57.99	.00
*	360	362	3.33	2.00	3.00	6.00	05/05/65	.500	.44	.00	04/30/65	05/05/65	04/30/65	05/05/65	*	.00
	360	363	3.33	2.00	3.00	6.00	05/05/65	.500	.44	.00	04/30/65	05/05/65	05/03/65	05/07/65	1.33	.00
	371	373	.00	.00	.00	.00	05/04/65	.500	.00	.00	05/04/65	05/04/65	07/27/65	07/27/65	57.99	.00
	373	387	8.00	7.00	8.00	9.00	05/14/65	.500	.11	.00	05/04/65	05/14/65	07/27/65	08/06/65	57.99	3.00
	371	392	10.50	8.00	10.00	15.00	05/19/65	.500	1.35	.00	05/04/65	05/19/65	09/03/65	09/21/65	86.16	.00
	363	367	.00	.00	.00	.00	05/05/65	.500	.00	.00	05/05/65	05/05/65	05/07/65	05/07/65	1.33	1.33
	401	896	.00	.00	.00	.00	05/05/65	.500	.00	.00	05/05/65	05/05/65	07/28/65	07/28/65	58.82	.00
*	362	367	1.33	1.00	1.00	3.00	05/07/65	.500	.11	.00	05/05/65	05/07/65	05/05/65	05/07/65	*	.00
	896	406	7.83	.00	8.00	15.00	05/17/65	.500	6.25	.00	05/05/65	05/17/65	07/28/65	08/09/65	58.82	.00
	393	399	.00	.00	.00	.00	05/07/65	.500	.00	.00	05/07/65	05/07/65	09/21/65	09/21/65	94.32	11.99
*	367	369	3.17	2.00	3.00	5.00	05/12/65	.500	.25	.00	05/07/65	05/12/65	05/07/65	05/12/65	*	.00
*	369	370	1.17	1.00	1.00	2.00	05/13/65	.500	.03	.00	05/12/65	05/13/65	05/12/65	05/13/65	*	.00
*	370	372	.00	.00	.00	.00	05/13/65	.500	.00	.00	05/13/65	05/13/65	05/13/65	05/13/65	*	.00
*	372	374	2.00	.00	2.00	4.00	05/17/65	.500	.44	.00	05/13/65	05/17/65	05/13/65	05/17/65	*	.00
	406	408	.00	.00	.00	.00	05/17/65	.500	.00	.00	05/17/65	05/17/65	08/09/65	08/09/65	58.82	58.82
*	374	376	.00	.00	.00	.00	04/26/65	.000	.00	-15.49	05/17/65	05/17/65	05/17/65	05/17/65	*	.00
	376	391	2.17	2.00	2.00	3.00	05/19/65	.500	.03	.00	05/17/65	05/19/65	08/04/65	08/06/65	54.99	.00
	376	378	5.00	2.00	5.00	8.00	05/24/65	.500	1.00	.00	05/17/65	05/24/65	05/18/65	05/25/65	.83	.00
*	376	379	11.33	8.00	10.00	20.00	06/02/65	.500	4.00	.00	05/17/65	06/02/65	05/17/65	06/02/65	*	.00
	391	387	.00	.00	.00	.00	05/19/65	.500	.00	.00	05/19/65	05/19/65	08/06/65	08/06/65	54.99	.00
	392	399	.00	.00	.00	.00	05/19/65	.500	.00	.00	05/19/65	05/19/65	09/21/65	09/21/65	86.16	3.83
	391	395	3.33	2.00	3.00	6.00	05/24/65	.500	.44	.00	05/19/65	05/24/65	09/15/65	09/21/65	82.33	.00
	387	420	20.00	10.00	20.00	30.00	06/17/65	.500	11.09	.00	05/19/65	06/17/65	08/06/65	09/03/65	54.99	54.99
	395	399	.00	.00	.00	.00	05/24/65	.500	.00	.00	05/24/65	05/24/65	09/21/65	09/21/65	82.33	.00
	399	402	.00	.00	.00	.00	05/25/65	.500	.00	.01	05/24/65	05/24/65	09/21/65	09/21/65	82.33	.00
	402	407	3.00	.00	3.00	6.00	05/27/65	.500	1.00	.00	05/24/65	05/27/65	09/21/65	09/24/65	82.33	.00
	378	381	5.50	3.00	5.00	10.00	06/01/65	.500	1.35	.00	05/24/65	06/01/65	05/25/65	06/02/65	.83	.83
	407	409	.00	.00	.00	.00	05/27/65	.500	.00	.00	05/27/65	05/27/65	09/24/65	09/24/65	82.33	.00
	409	441	20.83	15.00	20.00	30.00	06/28/65	.500	6.25	.00	05/27/65	06/28/65	09/24/65	10/25/65	82.33	82.33
*	379	381	.00	.00	.00	.00	06/02/65	.500	.00	.00	06/02/65	06/02/65	06/02/65	06/02/65	*	.00
*	381	382	3.00	2.00	3.00	4.00	06/07/65	.500	.11	.00	06/02/65	06/07/65	06/02/65	06/07/65	*	.00
*	382	383	3.17	2.00	3.00	5.00	06/10/65	.500	.25	.00	06/07/65	06/10/65	06/07/65	06/10/65	*	.00
	382	397	2.83	2.00	3.00	3.00	06/10/65	.500	.03	.00	06/07/65	06/10/65	09/16/65	09/21/65	71.17	.00
*	383	384	.00	.00	.00	.00	06/10/65	.500	.00	.00	06/10/65	06/10/65	06/10/65	06/10/65	*	.00
	397	418	7.83	5.00	8.00	10.00	06/22/65	.500	.69	.00	06/10/65	06/22/65	09/21/65	10/01/65	71.17	.00
*	384	385	8.83	6.00	8.00	15.00	06/23/65	.500	2.25	.00	06/10/65	06/23/65	06/10/65	06/23/65	*	.00
	418	423	.00	.00	.00	.00	06/22/65	.500	.00	.00	06/22/65	06/22/65	10/01/65	10/01/65	71.17	.00
	423	428	5.00	.00	5.00	10.00	06/29/65	.500	2.76	.00	06/22/65	06/29/65	10/01/65	10/08/65	71.17	.00
*	385	386	6.33	4.00	6.00	10.00	07/02/65	.500	1.00	.00	06/23/65	07/02/65	06/23/65	07/02/65	*	.00

B J PERT STATUS AS OF 15 FEB 65

START NODE	END NODE	MEAN TIME	OPT	MOST LIKELY	PESS	TS(EF)	PROB	VAR	TS-EF	EARLY START	EARLY FINISH	LATE START	LATE FINISH	TOTAL FLOAT	FREE FLOAT
385	396	10.67	5.00	11.00	15.00	07/09/65	.500	2.76	.00	06/23/65	07/09/65	09/07/65	09/21/65	51.33	.00
428	440	.00	.00	.00	.00	06/29/65	.500	.00	.00	06/29/65	06/29/65	10/08/65	10/08/65	71.17	67.34
* 386	388	.00	.00	.00	.00	07/02/65	.500	.00	.00	07/02/65	07/02/65	07/02/65	07/02/65	*	.00
* 388	389	8.83	6.00	8.00	15.00	07/15/65	.500	2.25	.00	07/02/65	07/15/65	07/02/65	07/15/65	*	.00
396	417	7.83	5.00	8.00	10.00	07/21/65	.500	.69	.00	07/09/65	07/21/65	09/21/65	10/01/65	51.33	.00
* 389	390	2.17	1.00	2.00	4.00	07/20/65	.500	.25	.00	07/15/65	07/20/65	07/15/65	07/20/65	*	.00
* 390	394	.00	.00	.00	.00	07/20/65	.500	.00	.00	07/20/65	07/20/65	07/20/65	07/20/65	*	.00
* 394	398	4.83	3.00	4.00	10.00	07/26/65	.500	1.35	.00	07/20/65	07/26/65	07/20/65	07/26/65	*	.00
417	422	.00	.00	.00	.00	07/21/65	.500	.00	.00	07/21/65	07/21/65	10/01/65	10/01/65	51.33	.00
422	427	5.00	.00	5.00	10.00	07/28/65	.500	2.76	.00	07/21/65	07/28/65	10/01/65	10/08/65	51.33	.00
* 398	400	.00	.00	.00	.00	06/24/65	.000	.00	-21.98	07/26/65	07/26/65	07/26/65	07/26/65	*	.00
* 400	404	5.67	4.00	5.00	10.00	08/03/65	.500	1.00	.00	07/26/65	08/03/65	07/26/65	08/03/65	*	.00
400	405	7.50	5.00	7.00	12.00	08/05/65	.500	1.35	.00	07/26/65	08/05/65	07/29/65	08/09/65	2.34	.00
400	403	15.00	8.00	15.00	22.00	08/16/65	.500	5.43	.00	07/26/65	08/16/65	08/27/65	09/20/65	23.34	.00
427	440	.00	.00	.00	.00	07/28/65	.500	.00	.00	07/28/65	07/28/65	10/08/65	10/08/65	51.33	47.50
* 404	408	4.17	3.00	4.00	6.00	08/09/65	.500	.25	.00	08/03/65	08/09/65	08/03/65	08/09/65	*	.00
405	408	.00	.00	.00	.00	08/05/65	.500	.00	.00	08/05/65	08/05/65	08/09/65	08/09/65	2.34	2.34
* 408	410	5.00	3.00	5.00	7.00	08/16/65	.500	.44	.00	08/09/65	08/16/65	08/09/65	08/16/65	*	.00
* 410	411	1.17	1.00	1.00	2.00	08/17/65	.500	.03	.00	08/16/65	08/17/65	08/16/65	08/17/65	*	.00
403	416	9.33	8.00	9.00	12.00	08/30/65	.500	.44	.00	08/16/65	08/30/65	09/20/65	10/01/65	23.34	.00
* 411	412	.00	.00	.00	.00	08/17/65	.500	.00	.00	08/17/65	08/17/65	08/17/65	08/17/65	*	.00
* 412	413	3.33	2.00	3.00	6.00	08/23/65	.500	.44	.00	08/17/65	08/23/65	08/17/65	08/23/65	*	.00
* 413	414	.00	.00	.00	.00	08/23/65	.500	.00	.00	08/23/65	08/23/65	08/23/65	08/23/65	*	.00
414	419	5.00	3.00	5.00	7.00	08/30/65	.500	.44	.00	08/23/65	08/30/65	08/24/65	08/31/65	1.00	.00
* 414	415	9.33	8.00	9.00	12.00	09/03/65	.500	.44	.00	08/23/65	09/03/65	08/23/65	09/03/65	*	.00
416	421	.00	.00	.00	.00	08/30/65	.500	.00	.00	08/30/65	08/30/65	10/01/65	10/01/65	23.34	.00
419	424	1.17	1.00	1.00	2.00	08/31/65	.500	.03	.00	08/30/65	08/31/65	08/31/65	09/01/65	1.00	.00
421	426	5.00	.00	5.00	10.00	09/07/65	.500	2.76	.00	08/30/65	09/07/65	10/01/65	10/08/65	23.34	.00
424	429	.00	.00	.00	.00	08/31/65	.500	.00	.00	08/31/65	08/31/65	09/01/65	09/01/65	1.00	.00
429	431	3.33	2.00	3.00	6.00	09/03/65	.500	.44	.00	08/31/65	09/03/65	09/01/65	09/07/65	1.00	.00
* 415	420	.00	.00	.00	.00	09/03/65	.500	.00	.00	09/03/65	09/03/65	09/03/65	09/03/65	*	.00
431	433	.00	.00	.00	.00	07/14/65	.000	.00	-37.82	09/03/65	09/03/65	09/07/65	09/07/65	1.00	.00
433	434	8.83	6.00	8.00	15.00	09/17/65	.500	2.25	.00	09/03/65	09/17/65	09/07/65	09/20/65	1.00	.00
415	425	10.00	8.00	10.00	12.00	09/20/65	.500	.44	.00	09/03/65	09/20/65	09/17/65	10/01/65	9.00	.00
* 420	435	10.00	5.00	10.00	15.00	09/20/65	.500	2.76	.00	09/03/65	09/20/65	09/03/65	09/20/65	*	.00
426	440	.00	.00	.00	.00	09/07/65	.500	.00	.00	09/07/65	09/07/65	10/08/65	10/08/65	23.34	19.51
434	435	.00	.00	.00	.00	09/17/65	.500	.00	.00	09/17/65	09/17/65	09/20/65	09/20/65	1.00	1.00
434	436	7.17	5.00	7.00	10.00	09/28/65	.500	.69	.00	09/17/65	09/28/65	09/23/65	10/04/65	3.83	.00
425	430	.00	.00	.00	.00	09/20/65	.500	.00	.00	09/20/65	09/20/65	10/01/65	10/01/65	9.00	.00
430	432	5.00	.00	5.00	10.00	09/27/65	.500	2.76	.00	09/20/65	09/27/65	10/01/65	10/08/65	9.00	.00
* 435	438	9.50	6.00	9.00	15.00	10/04/65	.500	2.25	.00	09/20/65	10/04/65	09/20/65	10/04/65	*	.00
432	440	.00	.00	.00	.00	09/27/65	.500	.00	.00	09/27/65	09/27/65	10/08/65	10/08/65	9.00	5.17
436	437	.00	.00	.00	.00	09/28/65	.500	.00	.00	09/28/65	09/28/65	10/04/65	10/04/65	3.83	.00
437	439	4.00	.00	4.00	8.00	10/04/65	.500	1.77	.00	09/28/65	10/04/65	10/04/65	10/08/65	3.83	.00
439	440	.00	.00	.00	.00	10/04/65	.500	.00	.00	10/04/65	10/04/65	10/08/65	10/08/65	3.83	.00
440	441	10.50	8.00	10.00	15.00	10/19/65	.500	1.35	.00	10/04/65	10/19/65	10/08/65	10/25/65	3.83	3.83
* 438	441	15.00	10.00	15.00	20.00	12/27/65	1.000	2.76	40.85	10/04/65	10/25/65	10/04/65	10/25/65	*	.00
* 441	442	14.67	8.00	15.00	20.00	11/12/65	.500	4.00	.00	10/25/65	11/12/65	10/25/65	11/12/65	*	.00
* 442	443	7.17	.00	7.00	15.00	11/23/65	.500	6.25	.00	11/12/65	11/23/65	11/12/65	11/23/65	*	.00
* 443	444	10.00	5.00	10.00	15.00	12/09/65	.500	2.76	.00	11/23/65	12/09/65	11/23/65	12/09/65	*	.00

B J PERT STATUS AS OF 15 FEB 65

	START NODE	END NODE	MEAN TIME	OPT	MOST LIKELY	PESS	TS(EF)	PROB	VAR	TS-EF	EARLY START	EARLY FINISH	LATE START	LATE FINISH	TOTAL FLOAT	FREE FLOAT
*	444	445	20.83	15.00	20.00	30.00	01/13/66	.500	6.25	.00	12/09/65	01/13/66	12/09/65	01/13/66	*	.00
*	445	866	.00	.00	.00	.00	01/13/66	.500	.00	.00	01/13/66	01/13/66	01/13/66	01/13/66	*	.00

PROJECT COMPLETION 228.82 PROJECT SLACK .00

DMJM DANIEL, MANN, JOHNSON, & MENDENHALL PLANNING § ARCHITECTURE § ENGINEERING § SYSTEMS	PERT STATUS REPORT NO. 9 BLH/VOITH As of: February 15, 1965 Distributed: March 2, 1965

PERT STATUS

BALDWIN-LIMA-HAMILTON/VOITH MODEL PUMP PROGRAM

Approved: Hans Gartmann
Hans Gartmann
Project Engineer

Distribution
Department of Water Resources
Baldwin-Lima-Hamilton
J. M. Voith

This report presents the current BLH/Voith Model Pump Program schedule derived from their PERT report for the period ending February 15, 1965.

Table I shows the current status of important events. Figure 1 indicates that the overall program schedule has improved by six (6) days during the period 1-15 February 1965. This improvement is the result of revised time estimates for activities 215-217 and 217-219 (Model Pump, 2-stage Double Flow installation and preliminary H-Q-Eff tests respectively).

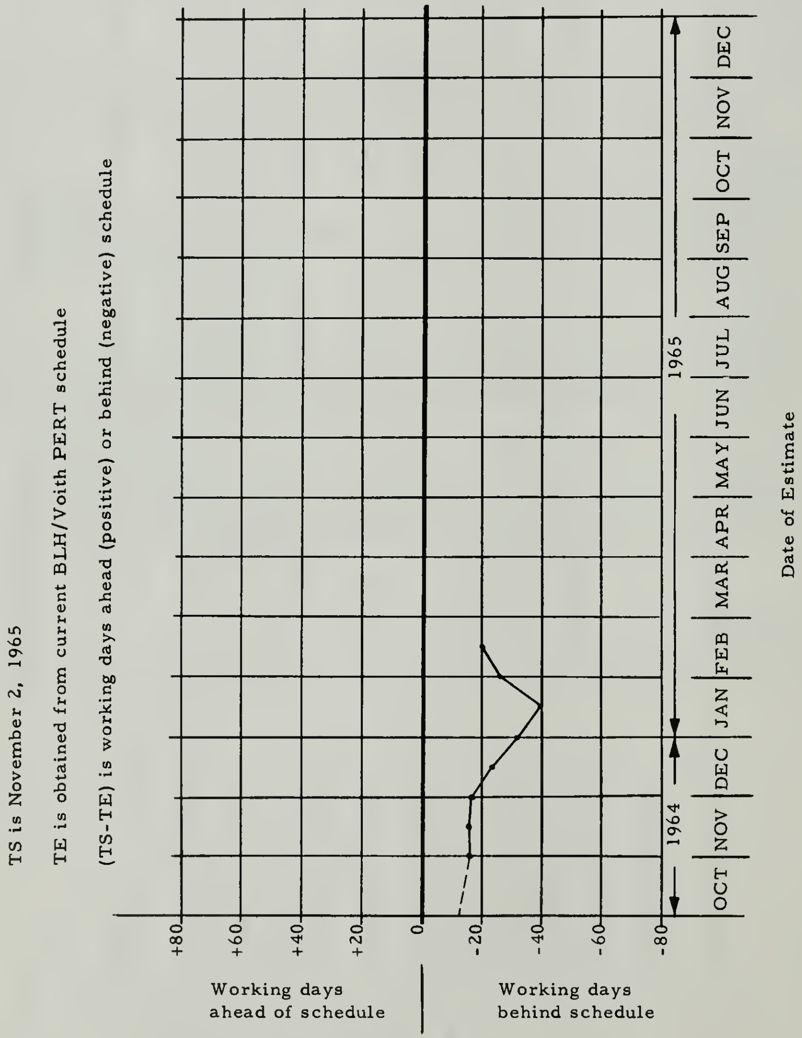
Activity No.	Description	Expected Early Start Date (ES)	Early Finish Date (EF)		Target Schedule Completion Date (TS)	TS-EF (working days)	
			Date Completed	Expected Completion Date		Days Ahead	Days Behind
211-212	Final Single Stage Model H, Q, EFF Tests		2-3-65		1-19-65		11
212-215	Workshop Assembly of Model, 2-Stage, D. F.	In Progress		2-22-65	3-9-65	11.00	
217-219	H, Q, EFF Preliminary Tests, 2-Stage, D. F. Model	3-1-65		3-5-65	4-8-65	23.83	
225-226	Final H, Q, EFF Tests, 2-Stage, D. F. Model	4-28-65		5-4-65	7-13-65	45.83	
237-238	3-Quadrant Tests	6-30-65		6-30-65	8-12-65	30.00	
243-245	Receipt of Preliminary Report	7-23-65		7-23-65	9-1-65	28.00	
250-251	Radial Thrust Tests	8-11-65		8-11-65	9-21-65	28.17	
262-263	Pressure Fluctuation Tests	9-29-65		9-29-65	10-6-65	4.51	
269-271	Receipt of Final Report Draft	11-11-65		12-1-65	11-2-65		20.32

TABLE I. BLH/VOITH IMPORTANT EVENTS STATUS

as of February 15, 1965

DMJM DANIEL, MANN, JOHNSON, & MENDENHALL
PLANNING • ARCHITECTURE • ENGINEERING • SYSTEMS

Figure 1. Status of Expected Delivery Date of BLH/Voith Final Report Draft



BLH/VOITH PERT STATUS AS OF 15 FEB 65

	START NODE	END NODE	MEAN TIME	OPT	MOST LIKELY	PESS	TS(EF)	PROB	VAR	TS-EF	EARLY START	EARLY FINISH	LATE START	LATE FINISH	TOTAL FLOAT	FREE FLOAT
	212	151	.00	.00	.00	.00	00/00/60	.000	.00	.00	02/16/65	02/16/65	02/24/65	02/24/65	6.34	.00
	151	184	2.83	.00	3.00	5.00	02/18/65	.500	.69	.00	02/16/65	02/18/65	02/24/65	03/01/65	6.34	.00
	151	185	2.83	.00	3.00	5.00	02/18/65	.500	.69	.00	02/16/65	02/18/65	05/11/65	05/14/65	58.34	.00
	151	186	2.83	.00	3.00	5.00	02/18/65	.500	.69	.00	02/16/65	02/18/65	06/25/65	06/30/65	88.17	.00
	151	187	2.83	.00	3.00	5.00	02/18/65	.500	.69	.00	02/16/65	02/18/65	08/09/65	08/11/65	118.00	.00
	212	216	8.00	6.00	8.00	10.00	02/26/65	.500	.44	.00	02/16/65	02/26/65	08/06/65	08/18/65	117.49	.00
*	212	215	4.00	3.00	4.00	5.00	03/09/65	1.000	.11	11.00	02/16/65	02/22/65	02/16/65	02/22/65	*	.00
	212	228	20.83	15.00	20.00	30.00	03/16/65	.500	6.25	.00	02/16/65	03/16/65	04/13/65	05/14/65	40.34	40.34
	184	217	.00	.00	.00	.00	02/18/65	.500	.00	.00	02/18/65	02/18/65	03/01/65	03/01/65	6.34	6.34
	185	228	.00	.00	.00	.00	02/18/65	.500	.00	.00	02/18/65	02/18/65	05/14/65	05/14/65	58.34	58.34
	186	238	.00	.00	.00	.00	02/18/65	.500	.00	.00	02/18/65	02/18/65	06/30/65	06/30/65	88.17	88.17
	187	251	.00	.00	.00	.00	02/18/65	.500	.00	.00	02/18/65	02/18/65	08/11/65	08/11/65	118.00	118.00
*	215	217	5.17	4.00	5.00	7.00	03/01/65	.500	.25	.00	02/22/65	03/01/65	02/22/65	03/01/65	*	.00
	216	231	8.00	6.00	8.00	10.00	03/10/65	.500	.44	.00	02/26/65	03/10/65	08/18/65	08/30/65	117.49	53.17
	216	241	12.83	10.00	13.00	15.00	03/16/65	.500	.69	.00	02/26/65	03/16/65	09/30/65	10/20/65	148.49	.00
*	217	219	4.00	3.00	4.00	5.00	04/08/65	1.000	.11	23.83	03/01/65	03/05/65	03/01/65	03/05/65	*	.00
*	219	220	4.00	3.00	4.00	5.00	03/11/65	.500	.11	.00	03/05/65	03/11/65	03/05/65	03/11/65	*	.00
*	220	221	8.00	6.00	8.00	10.00	03/23/65	.500	.44	.00	03/11/65	03/23/65	03/11/65	03/23/65	*	.00
	241	243	.00	.00	.00	.00	03/16/65	.500	.00	.00	03/16/65	03/16/65	10/20/65	10/20/65	148.49	86.17
*	221	222	4.00	3.00	4.00	5.00	03/29/65	.500	.11	.00	03/23/65	03/29/65	03/23/65	03/29/65	*	.00
*	222	223	8.00	6.00	8.00	10.00	04/08/65	.500	.44	.00	03/29/65	04/08/65	03/29/65	04/08/65	*	.00
*	223	224	4.00	3.00	4.00	5.00	04/14/65	.500	.11	.00	04/08/65	04/14/65	04/08/65	04/14/65	*	.00
*	224	225	8.00	6.00	8.00	10.00	04/28/65	.500	.44	.00	04/14/65	04/28/65	04/14/65	04/28/65	*	.00
*	225	226	4.00	3.00	4.00	5.00	07/13/65	1.000	.11	45.83	04/28/65	05/04/65	04/28/65	05/04/65	*	.00
*	226	228	8.00	6.00	8.00	10.00	05/14/65	.500	.44	.00	05/04/65	05/14/65	05/04/65	05/14/65	*	.00
	228	229	8.00	6.00	8.00	10.00	05/26/65	.500	.44	.00	05/14/65	05/26/65	08/18/65	08/30/65	64.32	.00
*	228	230	4.00	3.00	4.00	5.00	05/20/65	.500	.11	.00	05/14/65	05/20/65	05/14/65	05/20/65	*	.00
*	230	232	8.00	6.00	8.00	10.00	06/02/65	.500	.44	.00	05/20/65	06/02/65	05/20/65	06/02/65	*	.00
	229	231	.00	.00	.00	.00	05/26/65	.500	.00	.00	05/26/65	05/26/65	08/30/65	08/30/65	64.32	.00
	229	233	12.83	10.00	13.00	15.00	06/16/65	.500	.69	.00	05/26/65	06/16/65	09/30/65	10/20/65	87.32	.00
	231	254	18.00	16.00	18.00	20.00	06/24/65	.500	.44	.00	05/26/65	06/24/65	08/30/65	09/23/65	64.32	41.66
*	232	234	4.00	3.00	4.00	5.00	06/09/65	.500	.11	.00	06/02/65	06/09/65	06/02/65	06/09/65	*	.00
*	234	235	8.00	6.00	8.00	10.00	06/22/65	.500	.44	.00	06/09/65	06/22/65	06/09/65	06/22/65	*	.00
	233	243	.00	.00	.00	.00	06/16/65	.500	.00	.00	06/16/65	06/16/65	10/20/65	10/20/65	87.32	25.00
*	235	236	.00	.00	.00	.00	06/22/65	.500	.00	.00	06/22/65	06/22/65	06/22/65	06/22/65	*	.00
*	236	237	5.83	4.00	6.00	7.00	06/30/65	.500	.25	.00	06/22/65	06/30/65	06/22/65	06/30/65	*	.00
	238	239	8.00	6.00	8.00	10.00	07/13/65	.500	.44	.00	06/30/65	07/13/65	09/27/65	10/07/65	62.32	.00
	238	240	4.00	3.00	4.00	5.00	07/07/65	.500	.11	.00	06/30/65	07/07/65	07/07/65	07/13/65	4.00	.00
*	238	242	8.00	6.00	8.00	10.00	07/13/65	.500	.44	.00	06/30/65	07/13/65	06/30/65	07/13/65	*	.00
*	237	238	.00	.00	.00	.00	08/12/65	1.000	.00	30.00	06/30/65	06/30/65	06/30/65	06/30/65	*	.00
	240	242	.00	.00	.00	.00	07/07/65	.500	.00	.00	07/07/65	07/07/65	07/13/65	07/13/65	4.00	4.00
	239	243	8.00	6.00	8.00	10.00	07/23/65	.500	.44	.00	07/13/65	07/23/65	10/07/65	10/20/65	62.32	.00
*	242	244	8.00	6.00	8.00	10.00	07/23/65	.500	.44	.00	07/13/65	07/23/65	07/13/65	07/23/65	*	.00
	243	245	.00	.00	.00	.00	09/01/65	1.000	.00	28.00	07/23/65	07/23/65	10/20/65	10/20/65	62.32	.00
*	244	246	8.00	6.00	8.00	10.00	08/04/65	.500	.44	.00	07/23/65	08/04/65	07/23/65	08/04/65	*	.00
	245	247	3.00	.00	3.00	6.00	07/28/65	.500	1.00	.00	07/23/65	07/28/65	10/20/65	10/25/65	62.32	.00
	247	249	.00	.00	.00	.00	07/28/65	.500	.00	.00	07/28/65	07/28/65	10/25/65	10/25/65	62.32	.00
	249	271	25.00	20.00	25.00	30.00	11/02/65	1.000	2.76	42.00	07/28/65	09/01/65	10/25/65	12/01/65	62.32	62.32
*	246	248	.00	.00	.00	.00	08/04/65	.500	.00	.00	08/04/65	08/04/65	08/04/65	08/04/65	*	.00
*	248	250	5.83	4.00	6.00	7.00	08/11/65	.500	.25	.00	08/04/65	08/11/65	08/04/65	08/11/65	*	.00

BLH/VOITH PERT STATUS AS OF 15 FEB 65

START NODE	END NODE	MEAN TIME	OPT	MOST LIKELY	PESS	TS(EF)	PROB	VAR	TS-EF	EARLY START	EARLY FINISH	LATE START	LATE FINISH	TOTAL FLOAT	FREE FLOAT
* 250	251	.00	.00	.00	.00	09/21/65	1.000	.00	28.17	08/11/65	08/11/65	08/11/65	08/11/65	*	.00
251	253	4.00	3.00	4.00	5.00	08/17/65	.500	.11	.00	08/11/65	08/17/65	08/24/65	08/30/65	8.83	.00
251	252	8.00	6.00	8.00	10.00	08/23/65	.500	.44	.00	08/11/65	08/23/65	09/13/65	09/23/65	22.66	.00
* 251	256	12.83	10.00	13.00	15.00	08/30/65	.500	.69	.00	08/11/65	08/30/65	08/11/65	08/30/65	*	.00
253	256	.00	.00	.00	.00	08/17/65	.500	.00	.00	08/17/65	08/17/65	08/30/65	08/30/65	8.83	8.83
252	254	.00	.00	.00	.00	08/23/65	.500	.00	.00	08/23/65	08/23/65	09/23/65	09/23/65	22.66	.00
252	255	8.00	6.00	8.00	10.00	09/02/65	.500	.44	.00	08/23/65	09/02/65	10/29/65	11/11/65	47.49	.00
254	267	8.00	6.00	8.00	10.00	09/02/65	.500	.44	.00	08/23/65	09/02/65	09/23/65	10/05/65	22.66	22.66
* 256	258	8.00	6.00	8.00	10.00	09/09/65	.500	.44	.00	08/30/65	09/09/65	08/30/65	09/09/65	*	.00
255	257	.00	.00	.00	.00	09/02/65	.500	.00	.00	09/02/65	09/02/65	11/11/65	11/11/65	47.49	.00
257	259	5.00	.00	5.00	10.00	09/09/65	.500	2.76	.00	09/02/65	09/09/65	11/11/65	11/19/65	47.49	.00
* 258	260	8.00	6.00	8.00	10.00	09/21/65	.500	.44	.00	09/09/65	09/21/65	09/09/65	09/21/65	*	.00
259	270	.00	.00	.00	.00	09/09/65	.500	.00	.00	09/09/65	09/09/65	11/19/65	11/19/65	47.49	25.66
* 260	261	.00	.00	.00	.00	09/21/65	.500	.00	.00	09/21/65	09/21/65	09/21/65	09/21/65	*	.00
* 261	262	5.83	4.00	6.00	7.00	09/29/65	.500	.25	.00	09/21/65	09/29/65	09/21/65	09/29/65	*	.00
* 262	263	.00	.00	.00	.00	10/06/65	.919	.00	4.51	09/29/65	09/29/65	09/29/65	09/29/65	*	.00
* 263	264	4.00	3.00	4.00	5.00	10/05/65	.500	.11	.00	09/29/65	10/05/65	09/29/65	10/05/65	*	.00
* 264	267	.00	.00	.00	.00	10/05/65	.500	.00	.00	10/05/65	10/05/65	10/05/65	10/05/65	*	.00
264	265	4.00	3.00	4.00	5.00	10/11/65	.500	.11	.00	10/05/65	10/11/65	11/08/65	11/12/65	21.83	.00
* 267	269	25.00	20.00	25.00	30.00	11/11/65	.500	2.76	.00	10/05/65	11/11/65	10/05/65	11/11/65	*	.00
265	266	.00	.00	.00	.00	10/11/65	.500	.00	.00	10/11/65	10/11/65	11/12/65	11/12/65	21.83	.00
266	268	4.00	.00	4.00	8.00	10/15/65	.500	1.77	.00	10/11/65	10/15/65	11/12/65	11/19/65	21.83	.00
268	270	.00	.00	.00	.00	10/15/65	.500	.00	.00	10/15/65	10/15/65	11/19/65	11/19/65	21.83	.00
270	271	8.00	6.00	8.00	10.00	11/02/65	.655	.44	1.51	10/15/65	10/28/65	11/19/65	12/01/65	21.83	21.83
* 269	271	12.83	10.00	13.00	15.00	11/02/65	.000	.69	-20.32	11/11/65	12/01/65	11/11/65	12/01/65	*	.00
* 271	272	19.67	13.00	20.00	25.00	12/29/65	.500	4.00	.00	12/01/65	12/29/65	12/01/65	12/29/65	*	.00
* 272	273	7.17	.00	7.00	15.00	01/12/66	.500	6.25	.00	12/29/65	01/12/66	12/29/65	01/12/66	*	.00
* 273	274	15.00	10.00	15.00	20.00	02/02/66	.500	2.76	.00	01/12/66	02/02/66	01/12/66	02/02/66	*	.00
* 274	275	8.00	6.00	8.00	10.00	02/14/66	.500	.44	.00	02/02/66	02/14/66	02/02/66	02/14/66	*	.00
* 275	866	.00	.00	.00	.00	02/14/66	.500	.00	.00	02/14/66	02/14/66	02/14/66	02/14/66	*	.00

PROJECT COMPLETION 247.16 PROJECT SLACK .00

DMJM DANIEL, MANN, JOHNSON, & MENDENHALL PLANNING • ARCHITECTURE • ENGINEERING • SYSTEMS	PERT STATUS REPORT NO. 8 AC/SULZER As of: February 15, 1965 Distributed: March 3, 1965

PERT STATUS

ALLIS-CHALMERS/SULZER MODEL PUMP PROGRAM

Distribution
Department of Water Resources
Allis-Chalmers
Sulzer Bros.

Approved: Hans Gartmann
Hans Gartmann
Project Engineer

This report presents the current AC/Sulzer Model Pump Program schedule derived from their PERT report for the period ending February 15, 1965.

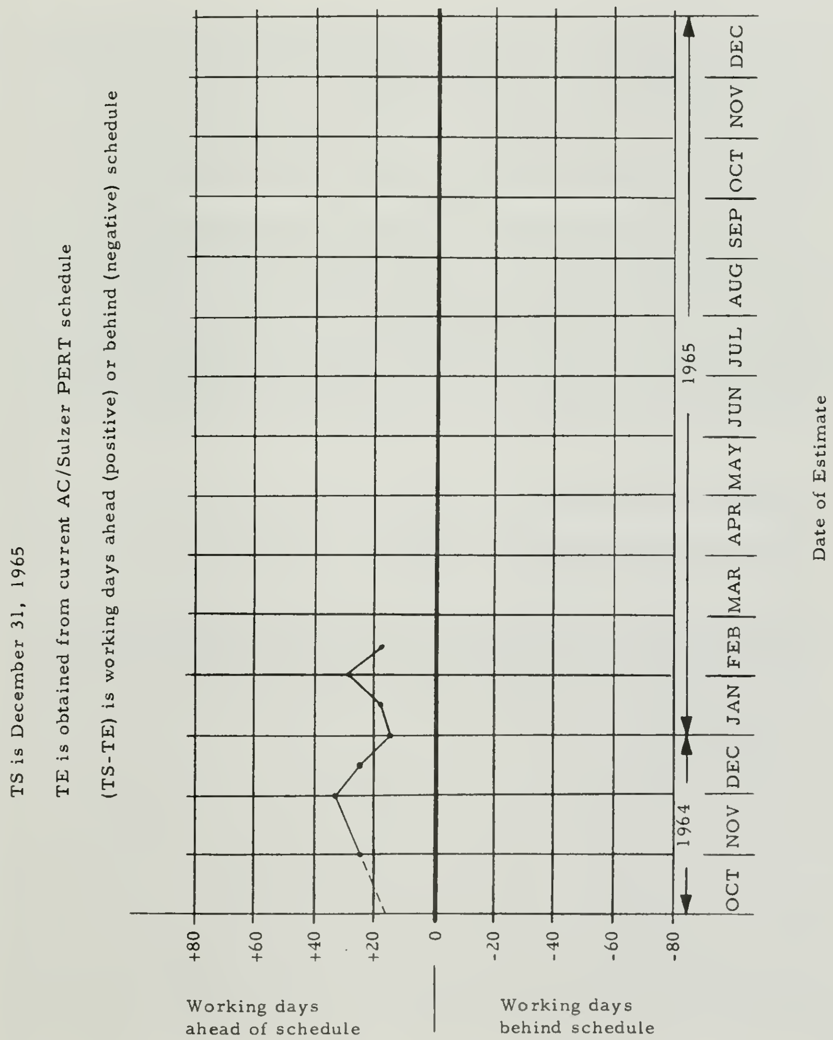
Table I shows that all testing will be completed September 9, 1965 which is 4 days behind schedule, but the overall program is approximately 17 days ahead of schedule.

Activity No.	Description	Expected Early Start Date (ES)	Early Finish Date (EF)		Target Schedule Completion Date (TS)	TS—EF (working days)	
			Date Completed	Expected Completion Date		Days Ahead	Days Behind
31-35	Workshop Assembly of Model		1-27-65		3-22-65	37	
30-32	Test Loop Assembly (for calibration)		1-27-65		3-22-65	37	
41-42	Pump Model #1 H-Q-EFF Tests	3-10-65		3-24-65	4-20-65	17	
69-71	Cavitation Tests	4-2-65		4-8-65	5-10-65	19.17	
90-92	Complete 3-Quadrant Testing	5-12-65		5-17-65	6-29-65	28.17	
44-46	Pump Model #2 H-Q-EFF Tests	5-24-65		6-9-65	7-14-65	24.17	
59-78	Receipt of Preliminary Report	6-11-65		6-11-65	7-19-65	25.17	
56-62	Complete Thrust Testing	8-5-65		8-5-65	8-13-65	5.83	
98-100	Complete Testing	9-1-65		9-8-65	9- 2-65		4.17
871-879	Receipt of Final Report Draft	10-8-65		12-6-65	12-31-65	17.16	

TABLE 1. AC/SULZER IMPORTANT EVENTS STATUS as of February 15, 1965

DMJM DANIEL, MANN, JOHNSON, & MENDENHALL
PLANNING • ARCHITECTURE • ENGINEERING • SYSTEMS

Figure 1. Status of Expected Delivery Date of AC/Sulzer Final Report Draft



AC/SULZER PERT STATUS AS OF 15 FEB 65

	START NODE	END NODE	MEAN TIME	OPT	MOST LIKELY	PESS	TS(EF)	PROB	VAR	TS-EF	EARLY START	EARLY FINISH	LATE START	LATE FINISH	TOTAL FLOAT	FREE FLOAT
	35	40	.00	.00	.00	.00	00/00/60	.000	.00	.00	02/16/65	02/16/65	04/08/65	04/08/65	36.83	.00
	40	70	2.00	2.00	2.00	2.00	02/18/65	.000	.00	.00	02/16/65	02/18/65	04/08/65	04/12/65	36.83	.00
	40	91	2.00	2.00	2.00	2.00	02/18/65	.000	.00	.00	02/16/65	02/18/65	08/17/65	08/19/65	125.17	.00
*	35	41	15.00	12.00	15.00	18.00	03/10/65	.500	1.00	.00	02/16/65	03/10/65	02/16/65	03/10/65	*	.00
	70	72	.00	.00	.00	.00	02/18/65	.000	.00	.00	02/18/65	02/18/65	04/12/65	04/12/65	36.83	.00
	91	93	.00	.00	.00	.00	02/18/65	.000	.00	.00	02/18/65	02/18/65	08/19/65	08/19/65	125.17	.00
	72	76	5.00	4.00	5.00	6.00	02/25/65	.500	.11	.00	02/18/65	02/25/65	04/12/65	04/21/65	36.83	.00
	93	96	5.00	4.00	5.00	6.00	02/25/65	.500	.11	.00	02/18/65	02/25/65	08/19/65	08/26/65	125.17	.00
	76	79	.00	.00	.00	.00	02/25/65	.500	.00	.00	02/25/65	02/25/65	04/21/65	04/21/65	36.83	36.83
	96	97	.00	.00	.00	.00	02/25/65	.500	.00	.00	02/25/65	02/25/65	08/26/65	08/26/65	125.17	125.17
*	41	42	10.00	8.00	10.00	12.00	04/20/65	1.000	.44	17.00	03/10/65	03/24/65	03/10/65	03/24/65	*	.00
	42	66	2.00	1.00	2.00	3.00	03/26/65	.500	.11	.00	03/24/65	03/26/65	03/31/65	04/02/65	5.00	.00
	42	43	5.00	4.00	5.00	6.00	03/31/65	.500	.11	.00	03/24/65	03/31/65	10/25/65	11/01/65	149.84	.00
*	42	65	5.00	4.00	5.00	6.00	03/31/65	.500	.11	.00	03/24/65	03/31/65	03/24/65	03/31/65	*	.00
	66	69	.00	.00	.00	.00	03/26/65	.500	.00	.00	03/26/65	03/26/65	04/02/65	04/02/65	5.00	5.00
*	65	69	2.00	1.00	2.00	3.00	04/02/65	.500	.11	.00	03/31/65	04/02/65	03/31/65	04/02/65	*	.00
	43	59	10.00	8.00	10.00	12.00	04/14/65	.500	.44	.00	03/31/65	04/14/65	11/01/65	11/15/65	149.84	38.83
*	69	71	4.83	3.00	5.00	6.00	05/10/65	1.000	.25	19.17	04/02/65	04/08/65	04/02/65	04/08/65	*	.00
	71	75	2.00	1.00	2.00	3.00	04/12/65	.500	.11	.00	04/08/65	04/12/65	04/15/65	04/21/65	5.00	.00
*	71	74	5.00	4.00	5.00	6.00	04/15/65	.500	.11	.00	04/08/65	04/15/65	04/08/65	04/15/65	*	.00
	71	51	7.00	5.00	7.00	9.00	04/21/65	.500	.44	.00	04/08/65	04/21/65	07/07/65	07/16/65	59.34	.00
	75	79	.00	.00	.00	.00	04/12/65	.500	.00	.00	04/12/65	04/12/65	04/21/65	04/21/65	5.00	5.00
*	74	79	2.00	1.00	2.00	3.00	04/21/65	.500	.11	.00	04/15/65	04/21/65	04/15/65	04/21/65	*	.00
	51	55	.00	.00	.00	.00	04/21/65	.500	.00	.00	04/21/65	04/21/65	07/16/65	07/16/65	59.34	.00
*	79	81	3.00	2.00	3.00	4.00	04/26/65	.500	.11	.00	04/21/65	04/26/65	04/21/65	04/26/65	*	.00
	51	59	10.00	8.00	10.00	12.00	05/05/65	.500	.44	.00	04/21/65	05/05/65	11/01/65	11/15/65	136.01	25.00
	55	60	10.00	8.00	10.00	12.00	05/05/65	.500	.44	.00	04/21/65	05/05/65	07/16/65	07/30/65	59.34	.00
*	81	84	5.00	4.00	5.00	6.00	05/03/65	.500	.11	.00	04/26/65	05/03/65	04/26/65	05/03/65	*	.00
	81	58	7.00	5.00	7.00	9.00	05/05/65	.500	.44	.00	04/26/65	05/05/65	07/21/65	07/30/65	59.34	.00
*	84	86	.00	.00	.00	.00	05/03/65	.500	.00	.00	05/03/65	05/03/65	05/03/65	05/03/65	*	.00
*	86	87	3.00	2.00	3.00	4.00	05/06/65	.500	.11	.00	05/03/65	05/06/65	05/03/65	05/06/65	*	.00
	58	59	10.00	8.00	10.00	12.00	05/19/65	.500	.44	.00	05/05/65	05/19/65	11/01/65	11/15/65	126.01	15.00
	60	68	10.00	8.00	10.00	12.00	05/19/65	.500	.44	.00	05/05/65	05/19/65	07/30/65	08/13/65	59.34	.00
	58	60	.00	.00	.00	.00	05/05/65	.500	.00	.00	05/05/65	05/05/65	07/30/65	07/30/65	59.34	.00
*	87	89	4.00	3.00	4.00	5.00	05/12/65	.500	.11	.00	05/06/65	05/12/65	05/06/65	05/12/65	*	.00
	87	64	7.00	5.00	7.00	9.00	05/17/65	.500	.44	.00	05/06/65	05/17/65	08/04/65	08/13/65	61.34	.00
*	89	90	.00	.00	.00	.00	05/12/65	.500	.00	.00	05/12/65	05/12/65	05/12/65	05/12/65	*	.00
*	90	92	3.00	2.00	3.00	4.00	06/29/65	1.000	.11	28.17	05/12/65	05/17/65	05/12/65	05/17/65	*	.00
	64	68	.00	.00	.00	.00	05/17/65	.500	.00	.00	05/17/65	05/17/65	08/13/65	08/13/65	61.34	2.00
*	92	44	5.00	4.00	5.00	6.00	05/24/65	.500	.11	.00	05/17/65	05/24/65	05/17/65	05/24/65	*	.00
	92	73	7.00	5.00	7.00	9.00	05/26/65	.500	.44	.00	05/17/65	05/26/65	08/18/65	08/27/65	64.34	.00
	64	59	10.00	8.00	10.00	12.00	06/01/65	.500	.44	.00	05/17/65	06/01/65	11/01/65	11/15/65	118.01	7.00
	68	77	10.00	8.00	10.00	12.00	06/03/65	.500	.44	.00	05/19/65	06/03/65	08/13/65	08/27/65	59.34	.00
*	44	46	10.00	8.00	10.00	12.00	07/14/65	1.000	.44	24.17	05/24/65	06/09/65	05/24/65	06/09/65	*	.00
	73	77	.00	.00	.00	.00	05/26/65	.500	.00	.00	05/26/65	05/26/65	08/27/65	08/27/65	64.34	5.00
	73	59	10.00	8.00	10.00	12.00	06/11/65	.500	.44	.00	05/26/65	06/11/65	11/01/65	11/15/65	111.01	.00
	77	101	10.00	8.00	10.00	12.00	06/18/65	.500	.44	.00	06/03/65	06/18/65	08/27/65	09/10/65	59.34	59.34
	46	48	4.00	3.00	4.00	5.00	06/15/65	.500	.11	.00	06/09/65	06/15/65	06/28/65	07/02/65	12.34	.00
	46	83	7.00	5.00	7.00	9.00	06/18/65	.500	.44	.00	06/09/65	06/18/65	10/28/65	11/08/65	101.01	.00
*	46	49	11.17	8.00	11.00	15.00	06/25/65	.500	1.35	.00	06/09/65	06/25/65	06/09/65	06/25/65	*	.00

AC/SULZER PERT STATUS AS OF 15 FEB 65

START NODE	END NODE	MEAN TIME	OPT	MOST LIKELY	PESS	TS(EF)	PROB	VAR	TS-EF	EARLY START	EARLY FINISH	LATE START	LATE FINISH	TOTAL FLOAT	FREE FLOAT
59	78	.00	.00	.00	.00	07/19/65	1.000	.00	25.17	06/11/65	06/11/65	11/15/65	11/15/65	111.01	.00
78	82	5.00	4.00	5.00	6.00	06/18/65	.500	.11	.00	06/11/65	06/18/65	11/15/65	11/22/65	111.01	.00
48	52	.00	.00	.00	.00	06/15/65	.500	.00	.00	06/15/65	06/15/65	07/02/65	07/02/65	12.34	12.34
82	85	.00	.00	.00	.00	06/18/65	.500	.00	.00	06/18/65	06/18/65	11/22/65	11/22/65	111.01	.00
83	82	.00	.00	.00	.00	06/18/65	.500	.00	.00	06/18/65	06/18/65	11/22/65	11/22/65	111.01	.00
83	107	10.00	8.00	10.00	12.00	07/02/65	.500	.44	.00	06/18/65	07/02/65	11/08/65	11/22/65	101.01	.00
85	879	10.00	8.00	10.00	12.00	07/02/65	.500	.44	.00	06/18/65	07/02/65	11/22/65	12/06/65	111.01	111.01
* 49	52	5.17	4.00	5.00	7.00	07/02/65	.500	.25	.00	06/25/65	07/02/65	06/25/65	07/02/65	*	.00
107	112	.00	.00	.00	.00	07/02/65	.500	.00	.00	07/02/65	07/02/65	11/22/65	11/22/65	101.01	.00
112	876	5.00	4.00	5.00	6.00	07/09/65	.500	.11	.00	07/02/65	07/09/65	11/22/65	11/29/65	101.01	.00
* 52	53	15.00	12.00	15.00	18.00	07/23/65	.500	1.00	.00	07/02/65	07/23/65	07/02/65	07/23/65	*	.00
876	878	.00	.00	.00	.00	07/09/65	.500	.00	.00	07/09/65	07/09/65	11/29/65	11/29/65	101.01	64.34
* 53	54	4.00	3.00	4.00	5.00	07/29/65	.500	.11	.00	07/23/65	07/29/65	07/23/65	07/29/65	*	.00
53	88	7.00	5.00	7.00	9.00	08/03/65	.500	.44	.00	07/23/65	08/03/65	10/28/65	11/08/65	69.67	.00
* 54	56	2.00	1.00	2.00	3.00	08/02/65	.500	.11	.00	07/29/65	08/02/65	07/29/65	08/02/65	*	.00
* 56	62	3.00	2.00	3.00	4.00	08/13/65	.992	.11	5.83	08/02/65	08/05/65	08/02/65	08/05/65	*	.00
88	106	10.00	8.00	10.00	12.00	08/17/65	.500	.44	.00	08/03/65	08/17/65	11/08/65	11/22/65	69.67	.00
62	95	5.00	4.00	5.00	6.00	08/12/65	.500	.11	.00	08/05/65	08/12/65	08/19/65	08/26/65	10.00	.00
62	94	7.00	5.00	7.00	9.00	08/16/65	.500	.44	.00	08/05/65	08/16/65	10/28/65	11/08/65	60.67	.00
* 62	97	15.00	12.00	15.00	18.00	08/26/65	.500	1.00	.00	08/05/65	08/26/65	08/05/65	08/26/65	*	.00
95	97	.00	.00	.00	.00	08/12/65	.500	.00	.00	08/12/65	08/12/65	08/26/65	08/26/65	10.00	10.00
94	105	10.00	8.00	10.00	12.00	08/30/65	.500	.44	.00	08/16/65	08/30/65	11/08/65	11/22/65	60.67	.00
106	111	.00	.00	.00	.00	08/17/65	.500	.00	.00	08/17/65	08/17/65	11/22/65	11/22/65	69.67	.00
111	875	5.00	4.00	5.00	6.00	08/24/65	.500	.11	.00	08/17/65	08/24/65	11/22/65	11/29/65	69.67	.00
875	878	.00	.00	.00	.00	08/24/65	.500	.00	.00	08/24/65	08/24/65	11/29/65	11/29/65	69.67	33.00
* 97	98	4.00	3.00	4.00	5.00	09/01/65	.500	.11	.00	08/26/65	09/01/65	08/26/65	09/01/65	*	.00
105	110	.00	.00	.00	.00	08/30/65	.500	.00	.00	08/30/65	08/30/65	11/22/65	11/22/65	60.67	.00
110	874	5.00	4.00	5.00	6.00	09/06/65	.500	.11	.00	08/30/65	09/06/65	11/22/65	11/29/65	60.67	.00
98	100	5.00	4.00	5.00	6.00	09/02/65	.067	.11	-4.17	09/01/65	09/08/65	09/08/65	09/15/65	5.00	.00
* 98	99	7.00	5.00	7.00	9.00	09/10/65	.500	.44	.00	09/01/65	09/10/65	09/01/65	09/10/65	*	.00
874	878	.00	.00	.00	.00	09/06/65	.500	.00	.00	09/06/65	09/06/65	11/29/65	11/29/65	60.67	24.00
100	103	7.00	5.00	7.00	9.00	09/17/65	.500	.44	.00	09/08/65	09/17/65	09/15/65	09/24/65	5.00	.00
* 99	101	.00	.00	.00	.00	09/10/65	.500	.00	.00	09/10/65	09/10/65	09/10/65	09/10/65	*	.00
99	104	10.00	8.00	10.00	12.00	09/24/65	.500	.44	.00	09/10/65	09/24/65	11/08/65	11/22/65	41.67	.00
* 101	102	10.00	8.00	10.00	12.00	09/24/65	.500	.44	.00	09/10/65	09/24/65	09/10/65	09/24/65	*	.00
103	102	.00	.00	.00	.00	09/17/65	.500	.00	.00	09/17/65	09/17/65	09/24/65	09/24/65	5.00	5.00
103	108	10.00	8.00	10.00	12.00	10/01/65	.500	.44	.00	09/17/65	10/01/65	11/08/65	11/22/65	36.67	.00
104	109	.00	.00	.00	.00	09/24/65	.500	.00	.00	09/24/65	09/24/65	11/22/65	11/22/65	41.67	.00
109	873	5.00	4.00	5.00	6.00	10/01/65	.500	.11	.00	09/24/65	10/01/65	11/22/65	11/29/65	41.67	.00
* 102	871	10.00	8.00	10.00	12.00	10/08/65	.500	.44	.00	09/24/65	10/08/65	09/24/65	10/08/65	*	.00
108	872	.00	.00	.00	.00	10/01/65	.500	.00	.00	10/01/65	10/01/65	11/22/65	11/22/65	36.67	.00
873	878	.00	.00	.00	.00	10/01/65	.500	.00	.00	10/01/65	10/01/65	11/29/65	11/29/65	41.67	5.00
872	877	5.00	4.00	5.00	6.00	10/08/65	.500	.11	.00	10/01/65	10/08/65	11/22/65	11/29/65	36.67	.00
877	878	.00	.00	.00	.00	10/08/65	.500	.00	.00	10/08/65	10/08/65	11/29/65	11/29/65	36.67	.00
878	879	5.00	4.00	5.00	6.00	10/15/65	.500	.11	.00	10/08/65	10/15/65	11/29/65	12/06/65	36.67	36.67
* 871	879	41.67	30.00	40.00	60.00	12/31/65	.999	25.00	17.16	10/08/65	12/06/65	10/08/65	12/06/65	*	.00
* 879	880	19.67	13.00	20.00	25.00	01/04/66	.500	4.00	.00	12/06/65	01/04/66	12/06/65	01/04/66	*	.00
* 880	881	5.17	4.00	5.00	7.00	01/11/66	.500	.25	.00	01/04/66	01/11/66	01/04/66	01/11/66	*	.00
* 881	882	15.00	10.00	15.00	20.00	02/01/66	.500	2.76	.00	01/11/66	02/01/66	01/11/66	02/01/66	*	.00
* 882	883	18.33	15.00	18.00	23.00	02/28/66	.500	1.77	.00	02/01/66	02/28/66	02/01/66	02/28/66	*	.00

AC/SULZER PERT STATUS AS OF 15 FEB 65

START NODE	END NODE	MEAN TIME	OPT	MOST LIKELY	PESS	TS(EF)	PROB	VAR	TS-EF	EARLY START	EARLY FINISH	LATE START	LATE FINISH	TOTAL FLOAT	FREE FLOAT
* 883	866	.00	.00	.00	.00	02/28/66	.500	.00	.00	02/28/66	02/28/66	02/28/66	02/28/66	*	.00

PROJECT COMPLETION 263.01 PROJECT SLACK .00

CHAPTER 3

TECHNICAL ADVISORY BOARD MINUTES

The Technical Advisory Board, formed by DMJM, met September 9, 10, and 11, 1963 and February 17, 18, and 19, 1964 to provide general guidance for the Tehachapi Pumping Plant Research and Development Program being conducted by DMJM. Detailed minutes of these two meetings were prepared and recorded in the following documents.

"Tehachapi Pumping Plant, Research and Development Program, Technical Advisory Board Meeting Minutes, September 9, 10, and 11, 1963", Daniel, Mann, Johnson, & Mendenhall, Los Angeles, California, October 18, 1963.

"Minutes, Meeting No. 2, Technical Advisory Board, February 17, 18, and 19, 1964", Daniel, Mann, Johnson, & Mendenhall, Los Angeles, California, March 18, 1964.

The basic findings of these meetings are summarized in the following discussion.

A. MEETING NO. 1, September 9, 10, and 11, 1963

1. Attendance

a. Members Present

(1) Irvan F. Mendenhall, President, DMJM (Chairman)

(2) John T. Clabby, Vice President, Systems Division, DMJM

(3) Peter Jaray, Vice Director, Chief Engineer, Motor-Columbus, Ltd.

(4) Shu Magota, Manager of Engineering, DMJM (Alternate Member)

(5) S. Logan Kerr, Consulting Hydraulic Engineer

(6) David R. Miller, Project Director, DMJM (Secretary)

b. DMJM Project Staff (all were not present for all sessions)

(1) Hans Gartmann, Project Engineer

(2) Ray A. Hall

(3) Ernest C. Cole

(4) Otto Hartmann

(5) Ray E. Westman

c. Invited Guests from the Department of Water Resources (DWR), State of California

(1) Donald P. Thayer, Chief, Dams and Plants Design Branch, Division of Design and Construction

(2) T. W. Troost, Chief, Mechanical-Electrical Design Section, Dams and Plants Design Branch, Division of Design and Construction

2. Findings

After a series of presentations by the project staff, the following findings were reported:

a. A single lift, single casing, multistage pump concept was established as feasible.

b. The feasibility of 3, 4, and 5 stage, single flow pumps was established. It was recommended that 2-stage, single flow and double flow pumps be further studied.

c. The use of modular models and high head testing was explored.

d. Replies of model testing firms to initial inquiries were reviewed and the conclusion was reached that additional information from the firms was required before final selection.

e. Mr. Troost briefed the Board on the observations of his tour of European pump manufacturing firms and pumping installations.

f. The staff was directed to initiate preparation of the detailed scope of work and contract provisions for the model testing work.

B. MEETING NO. 2, February 17, 18, and 19, 1964

1. Attendance

a. Members Present

(1) Irvan F. Mendenhall, President, DMJM (Chairman)

(2) John T. Clabby, Vice President, Systems Division, DMJM

(3) Austin H. Church, Visiting Professor, Duke University

(4) S. Logan Kerr, Consulting Hydraulic Engineer

(5) Otto J. Hartmann, Senior Engineer, Motor-Columbus, Ltd. (Alternate for Peter Jaray, Motor-Columbus, Ltd.)

(6) L. J. Hooper, Director, Alden Hydraulic Laboratory, Worcester Polytechnic Institute

b. DMJM Project Staff (all were not present for all sessions)

(1) David R. Miller, Project Director

(2) Hans Gartmann, Project Engineer

(3) James D. Reiter

(4) Ernest C. Cole

(5) Wallace Dela Barre

(6) Ray E. Westman

(7) Others - as indicated by minutes

c. Department of Water Resources (DWR), State of California

(1) T. W. Troost, Chief, Mechanical-Electrical Design Section, Dams and Plants Design Branch, Division of Design and Construction

(2) Anthony Hunter, Head, Mechanical Unit, Southern District

(3) Henry Markosian, Head, Electrical Unit, Southern District

d. Metropolitan Water District (MWD)

(1) Robert A. Skinner, Chief Engineer and General Manager

(2) E. W. Rockwell, Chief Electrical Engineer

(3) W. Paul Winn, Senior Engineer

e. Others

(1) John Parmakian, Consulting Engineer (Liaison from Tehachapi Crossing Consulting Board - TCCB)

2. Summary, Findings, and Board Recommendations

a. Members of the Technical Advisory Board (TAB) were briefed on the results of the program to date.

(1) DMJM's role and authority in the program, and the responsibilities that lie with the DWR, the MWD, the TCCB, and others were discussed.

(2) The Board was appraised of the MWD position favoring a multilift concept for the Tehachapi lift, the MWD being concerned with reliability of the total system along with its cost, and the fact that the MWD had retained the Bechtel Corporation to make independent studies of various aspects of the problem.

(3) Regarding the advisability and desirability of having a program of close coordination established between the various groups and entities concerned with the program, it was specifically suggested that any Bechtel Corporation field work be coordinated with the DMJM field investigation program and that DMJM establish a liaison system with the MWD and/or the Bechtel Corporation. Further, it was explained to the Board that Mr. John Parmakian has been appointed by the TCCB to serve as liaison to the TAB of DMJM to facilitate coordination.

(4) The results of DWR cost comparison studies of the apparent four best alternates from the standpoint of economy were presented. It was

pointed out that the DWR currently favors the single lift, surface plant, underground penstock scheme because of inherent dangers with an underground plant and in view of the recommendations of the TCCB.

(5) The following recommendations and findings made by the TCCB at their recent meetings held on January 8, 9, and 10, 1964 were presented.

(a) No further consideration should be given to an underground pumping plant for geological, seismic, and safety reasons.

(b) That multistage pumps be analyzed from the standpoint of a four-stage unit only, and that no further consideration be given to three- or five-stage pumps.

(c) That further studies in regard to a two-stage, back-to-back pump or a system of two single-stage pumps in series for a single lift be abandoned.

(d) Recommended against further consideration of the Pastoria Creek route for the multilift system for seismic reasons. Recommended that an alignment for a multilift scheme be considered along roughly the same alignment as currently being considered for the single-lift concept.

(e) Recommended balancing tanks be used in lieu of reservoirs in connection with the multilift concept.

(f) Found that motors of speeds 900 RPM or greater to be unacceptable.

(g) Recommended against the use of suction boosters.

(h) Recommended that no further consideration be given to the "air-shroud" principle as proposed by Dominion Engineering.

(i) The TCCB recommended the pump testing scheme be limited to a four-stage model for a single-lift plan and a two-stage back-to-back model for study in connection with a two-lift plan.

(j) In the general discussion that followed, DMJM project staff members pointed out to the TAB that DMJM's presentation to the TCCB was a progress report and that it was not realized that the TCCB was prepared

to make recommendations based upon the material presented to them at that time. It was the consensus of the DMJM staff that many of these matters deserved more careful analysis and study before decisions should be finalized. It was pointed out that DMJM, therefore, felt impelled to present the information to the TAB for their individual and joint conclusions and recommendations.

(6) The TAB was briefed on the current status of the program with regard to the number of concepts currently being considered along with the appropriate applications of the various types of pumping machinery to each of the various lift concepts.

b. <u>Staff Presentations</u>

Presentations were made by the DMJM Project Staff in the following sequence. A general discussion of each item was held.

(1) Review of basic lift concepts.

(2) The balancing tank method of flow regulation.

(3) Pump alternatives being considered.

These are the 4-stage pump for the single-lift concept; the back-to-back, two-stage, single flow and the two-stage, double flow pumps for the two-lift concept; and the single stage, single flow, 2060 and 1600 specific speed pumps for the three-lift concept.

(4) Motor study.

(5) Model test firm evaluation procedure.

(6) Presentation of proposals from model testing firms.

A verbal resume was presented to the Board of the written proposals received by DMJM on February 10, 1964 from the following firms:

(a) Allis-Chalmers and Sulzer Bros. (joint venture)

(b) Byron Jackson

(c) Baldwin-Lima-Hamilton and J. M. Voith (joint venture)

(d) Newport News Shipbuilding and Drydock Company and Escher Wyss (joint venture)

c. Model Test Firm Presentations

Presentations were made by each of the above model test firms. A question and answer period followed each presentation.

d. DMJM Staff Evaluation of Model Test Proposals

A summary of the written and verbal proposals was presented by the project staff. This summary covered the extent of the proposal, where they intend to perform the work, the impeller diameters suggested, the testing horsepower available, the proposed model test pressures, the time required for testing, and finally the unit costs and combinations for the various models. The selection procedure included such major elements as time, the management plan, the program approach, the manufacturing facilities available, the test facilities proposed to be used, the individual and collective experience with the various types of pumping machinery, and cost. Based on these considerations, the staff recommended Baldwin-Lima-Hamilton as the successful proposer. Following a general discussion, it was concluded that a decision should be made by the TAB as to the advisability of pursuing the three major lift concepts under consideration and the adoption or rejection of the five basic models proposed to be tested prior to recommending the firm or firms to do the model testing work.

e. Presentation and Consideration of Lift Concepts

After general discussion of the technical feasibility of the various concepts, the Board affirmed the technical feasibility of all three lift concepts. There was also general agreement that in addition to technology, cost and reliability should be considered.

f. Presentation and Consideration of Pump Alternates

By voice vote, the TAB voted unanimously for the acceptance of the DMJM Staff recommendations for the inclusion of the basic five models in the model test program. These include the 4-stage, single flow, 600 RPM, 2095 specific speed model applicable to the single lift concept; the 2-stage, single flow, back-to-back impeller arrangement, 400 RPM, 1970 specific speed, and the 2-stage, double flow, 600 RPM, 2090 specific speed models applicable to the 2-lift concept; and the single stage, single flow, 514 RPM,

2060 specific speed, and the single stage, single flow, 400 RPM, 1600 specific speed models applicable to the 3-lift concept.

g. Discussion of Model Test Firm Proposals and Selection of Successful Firm

The Board recommended that AC/Sulzer be awarded the four-stage model with the provision that they be required to test to at least 80 percent prototype head. The Board recommended that the 2-stage, single flow, back-to-back and the 2-stage, double flow models be awarded to BLH/Voith with the stipulation that the liquidated damages objections could be satisfactorily ironed out within the framework of the specifications by DMJM Staff. The Board recommended that the single stage, single flow, 2060 and 1600 specific speed models be awarded to Byron Jackson with the stipulation that they be required to perform Phase I tests (H, Q, Efficiency Performance Tests) in 365 days or less.

A discussion followed in which all of the Board members agreed that the various stipulations and conditions mentioned in the motions should be resolved by the DMJM Staff. In the event that one or more of the firms decide not to agree to the stipulations and conditions and further indicate an unwillingness to negotiate, then they shall be notified that the Staff is not in a position to recommend an award and that a telephone or telegram poll be made of the Board members for future action.

h. Presentation of DMJM Staff Program - Phase I

A presentation was made of DMJM Staff recommendations for work and tasks remaining to be done during the Phase I portion of the program. Reference was made to a document entitled "Tehachapi Pumping Plant Research and Development Program, Phase I - Program Approach" dated February 17, 1964. This included the following major tasks:

(1) Management Control

(2) Model Testing Program

(3) Pump Research Study

(4) Wear Test Program

(5) Electric Motor Study

(6) Valve Study

(7) Control and Instrumentation Study

(8) Facility Study

(9) Reliability Study

(10) Hydraulic Transient Study

(11) Report

i. Wear Test Program Presentation and Discussion

A verbal presentation was made of the DMJM Staff's proposed wear test program as presented in the TAB briefing report. The Board recommended that the Wear Test Program proceed, that the DMJM Staff develop cost estimates and that if funding can be arranged, both types of testing (a stationary tester and a rotating tester) be utilized.

j. Presentation of DMJM Staff Program for Reliability Studies

In summary, the proposed reliability study will forecast the reliability of individual components and the total system. It will forecast or show the availability, or lack of availability, of the various components and the total system.

A discussion followed indicating that DMJM may not necessarily be concerned with interface items outside the pumping equipment itself; that is, DWR may elect to coordinate with DMJM in furnishing information concerning such things as power source and facility study items, penstocks and switchgear.

The discussion was summarized by stating that the information given was by way of briefing to the Board members and others to let those persons in the program know what DMJM is thinking and that DMJM requests further guidance from the State as to proper cut-off points regarding the extent of activity that DMJM should undertake in connection with the pump and motor study.

FORM 2—APPROVED BY THE ATTORNEY GENERAL (REV. 10-50)

CONTRACTOR—( )
STATE AGENCY—( )
DEPT. OF FINANCE—( )
CONTROLLER—( )

STATE OF CALIFORNIA
STANDARD AGREEMENT

NUMBER 352876

THIS AGREEMENT, Made and entered into this 15th day of July, 1963, at Sacramento, County of Sacramento, State of California, by and between State of California, through its duly elected or appointed, qualified and acting

Director (Title of officer acting for State) DEPARTMENT OF WATER RESOURCES (Department or other agency)

hereinafter called the State, and

Daniel, Mann, Johnson and Mendenhall,

hereinafter called the Contractor.

WITNESSETH: That the Contractor for and in consideration of the covenants, conditions, agreements, and stipulations of the State hereinafter expressed, does hereby agree to furnish to the State services and materials, as follows:

(Set forth service to be rendered by Contractor, amount to be paid Contractor, time for performance or completion, and attach plans and specifications, if any.)

(See reverse side hereof and following ten sheets, each bearing name of Contractor.)

These services may be properly secured outside of civil service procedures.
STATE PERSONNEL BOARD
By: D. Sharp Date 8/12/63

The provisions on the reverse side hereof constitute a part of this agreement.

IN WITNESS WHEREOF, This agreement has been executed, in quadruplicate, by and on behalf of the parties hereto, the day and year first above written.

STATE OF CALIFORNIA

DEPARTMENT OF WATER RESOURCES (Name of State agency)

By W. E. Warne

Director (Title)

Daniel, Mann, Johnson and Mendenhall (a corporation)
Contractor (If other than an individual, state whether a corporation, partnership, etc.)

By S. Kenneth Johnson
Executive Vice President

3325 Wilshire Blvd.
Los Angeles 5, California
Address

6 30.73 Jt 19 (Continued on 10 sheets, each bearing name of Contractor)

DO NOT WRITE IN THIS SPACE

DEPARTMENT OF FINANCE
APPROVED
AUG 29 1963
HALE CHAMPION, Director
Administrative Adviser

Disbursement from WRRF Fund Item 2608 Ch 1050/63
Reimbursement from Calif. Water Sec 12938 Fund Item Cat 2 Ch 1763/59 Code 639

F.Y.	Account No.	Organ No.	Exp. Code	Budget Item No	Encumbrance Amount	Unenc. Bal.
64	573	5001	3470228		225,000.00	55,000.00

I Hereby Certify upon my own personal knowledge that the unencumbered balance of the departmental budget provision for the period stated above is correct.

After T.B.A. No. ______ or B.R. No. ______)

Harry S. Keihorn — Signature of Accounting Officer — 8/63 Date

THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES

DWR 627 (Rev. 4-62) FUNDING STRIP

1. The State hereby agrees to pay for the services and materials at the times, in the manner and for the consideration, herein expressed.

2. The Contractor agrees to indemnify and save harmless the State, its officers, agents and employees from any and all claims and losses accruing or resulting to any and all contractors, subcontractors, materialmen, laborers and any other person, firm or corporation furnishing or supplying work, services, materials or supplies in connection with the performance of this contract, and from any and all claims and losses accruing or resulting to any person, firm or corporation who may be injured or damaged by the Contractor in the performance of this contract. The Contractor shall provide necessary workman's compensation insurance at Contractor's own cost and expense.

3. The parties hereto agree that the Contractor, and any agents and employees of Contractor, in the performance of this agreement, shall act in an independent capacity and not as officers or employees or agents of State of California.

4. The State may terminate this agreement and be relieved of the payment of any consideration to Contractor should Contractor fail to perform the covenants herein contained at the time and in the manner herein provided. In the event of such termination the State may proceed with the work in any manner deemed proper by State. The cost to the State shall be deducted from any sum due the Contractor under this agreement, and the balance, if any, shall be paid the Contractor upon demand.

5. This agreement is not assignable by Contractor either in whole or in part.

6. Time is of the essence of each and all the provisions of this agreement, and the provisions of this agreement shall extend to and be binding upon and inure to the benefit of the heirs, executors, administrators, successors, and assigns of the respective parties hereto.

7. It is mutually understood and agreed that no alteration or variation of the terms of this contract shall be valid unless made in writing and signed by the parties hereto, and that no oral understandings or agreements not incorporated herein, and no alterations or variations of the terms hereof unless made in writing between the parties hereto shall be binding on any of the parties hereto.

1. Contractor shall carry out a research and development program along with related engineering work for the Tehachapi Pumping Plant and shall furnish consulting services to State in connection with this facility as required. The program will cover research, development and engineering activities relative to the pumping installations including, but not limited to, the following:

a. Analysis of previous studies. State shall provide Contractor with all previous studies performed leading to the preliminary selection of type and number of pumps including the report prepared by State entitled "Preliminary Engineering Study of Plant Layouts Using Multistage Pump Units -- Tehachapi Pumping Plant," April, 1962. Contractor shall review these studies as background material forming the basis for the work under this contract and shall analyze and report any disagreement it may have with the conclusions therein for resolution by State before it proceeds with the work. Contractor shall perform such other studies of possible alternative programs as may be requested by State.

b. Analysis and recommendations for model testing program. Contractor shall study and ascertain requirements for a model testing program for the pumps and shall prepare specifications for such a program, after reviewing preliminary specifications developed by State.

c. Selection of a model testing firm and the execution of a contract for the model testing work. Contractor shall investigate the various pump manufacturing firms or

other institutions having hydraulic machinery testing laboratories, to determine which firm or institution, in its opinion, can best accomplish the model testing and shall recommend to the State the selection of that firm or institution. Upon the concurrence of the Department of Water Resources and the Department of Finance in said selection and approval by said Departments of the form of the model testing subcontract, Contractor shall execute a subcontract with the selected firm or institution for the performance of the model testing required. Contractor shall handle the details of contract preparation and execution.

d. <u>The administration of the model testing subcontract and witnessing the research and development work at the model testing laboratories</u>. Contractor shall administer all details of the model testing subcontract. Contractor shall establish a resident office at the test laboratory location and qualified personnel of Motor-Columbus, Ltd. or Contractor assigned to the project shall witness all tests. Contractor, in cooperation with the model testing firm, shall formulate procedures for conducting the model tests. Reports on the progress of model testing shall be furnished to State weekly in accordance with the provisions of Section 3 hereof.

e. <u>Investigation, study, and analysis of pumps</u>. Contractor shall perform an investigation, study, and analysis of pumps and related plant features to determine the most feasible and economical type of pumping facility. Contractor shall initiate such studies as soon as possible in order to provide State with preliminary recommendations. Factors to

be considered by Contractor shall include efficiency, operation and maintenance characteristics, pumping plant equipment, reliability and compatibility with related pumping plant components such as motors, valves and penstocks, as well as any additional factors that should be evaluated in determining the optimum type of pumping system. State shall furnish to Contractor cost data on equipment appurtenant to pumps, and on plant construction, as such may be required in pump selection

Contractor shall conduct normal operation and transient behavior studies of the pumps to determine the design characteristics for the pumps and appurtenant equipment. Such studies shall include analysis of the four quadrant pump characteristics and water hammer analysis of the penstock system. Complete step by step calculations shall be made of all surge conditions to determine transient pressures for penstock design and discharge valve operating time. The studies shall include determination of starting, stopping, and emergency operation conditions. Motor starting, pump motor thrust bearing, pump foundation anchorage, space requirements, and the effect of individual pump failure on the operation of remaining parallel pumps shall be determined. Investigations shall also be conducted of resonant effect in the discharge pipes resulting from pressure oscillations. Contractor shall carry out such other studies of related plant features as may be requested by State.

f. Submission of a final report. The results of the studies together with the model testing reports shall be assembled in a final report to State. The report shall include a draft of the technical portion of the specifications for procurement of the prototype pumps. State desires that these specifications shall be such as to allow the widest possible competitive bidding to the extent consistent with obtaining optimum characteristics. Fifty copies of the final report, with one set of reproducible auto-positives, together with photographs of the models and test facilities shall be furnished to the Department. The report size shall be approximately 8-1/2 x 11 inches.

2. The services to be rendered by Contractor under this contract shall be rendered through Contractor's own personnel and also through the personnel of the firm of Motor-Columbus, Ltd. of Baden, Switzerland (hereinafter "Motor-Columbus") which firm shall be engaged as a subcontractor by Contractor. State shall have no obligation under this contract unless Contractor executes a subcontract with Motor-Columbus which is consistent with this contract, and which provides for the contribution of the experience of Motor-Columbus to the work required hereunder and makes the personnel of Motor-Columbus available for advice and engineering on the technical problems involved in the performance of such work. Contractor shall permit the Department of Water Resources and the Department of Finance to examine the proposed form of subcontract with Motor-Columbus and shall incorporate therein any reasonable changes suggested by said Departments to insure Motor-Columbus participation, as described in the preceding sentence, in the work hereunder.

Contractor's Project Director shall be Mr. D. R. Miller and the Project Engineer shall be Mr. L. H. Kessler. Mr. I. E. Mendenhall, and Mr. John Clabby of Daniel, Mann, Johnson and Mendenhall, Mr. Peter Jaray of Motor-Columbus, Ltd., and Mr. S. Logan Kerr, Special Consultant, shall act as a Technical Advisory Board during the performance of the work.

Contractor agrees that all persons assigned to perform the services required by this contract shall possess experience and qualifications acceptable to State. At any time during the contract period, Contractor will, at the request of State, and may, with the concurrence of State, remove, reassign, or replace any person or persons assigned by Contractor to the contract work.

3. Contractor shall transmit weekly reports which shall describe all activities of the Contractor pertaining to the work hereunder during the preceding week. Contractor shall include in said weekly reports preliminary copies of data obtained and studies made, conclusions reached on problems under study, a list of personnel engaged in the work, and all other data necessary to permit an evaluation of the progress of the work. Said reports shall be sent to Mr. Donald P. Thayer, Chief, Dams and Plants Design Branch, Division of Design and Construction, Sacramento, California. Contractor shall present oral briefings on the progress of the studies to State personnel when requested by State. It is contemplated that State personnel shall inspect the work hereunder, including the model testing, from time to time as said work progresses, and Contractor shall give State such notice of the scheduling of said work as will permit State sufficient time to arrange to have its personnel present at the work site.

4. Alfred R. Golze, Chief Engineer, Department of Water Resources will act as State representative in connection with this contract and all official correspondence shall be addressed to him, other than the reports specified in Article 3. Mr. Golze will designate in writing representatives to act for him.

5. Any information, data, or material, including, without limitation, any work papers, drawings, designs, or specifications, supplied or generated pursuant to this contract shall become the property of State and shall be delivered to State upon the conclusion of Contractor's work hereunder. Such information, data or material shall not be transmitted to others than the State, including the press, without the written permission of State.

6. State, at its option, may terminate this contract at any time upon thirty days' written notice to Contractor. The model testing subcontract and the subcontract with Motor-Columbus shall contain appropriate provisions which will allow Contractor to terminate them upon State's request. In the event of termination of this contract by State, Contractor shall be paid for all work performed and expenses incurred pursuant to this contract to the date of termination. Contractor, in the event of such termination, shall complete such work as is necessary to put the work files in order and to summarize the work accomplished to the termination date in a report to State.

7. State shall compensate Contractor for its work on the following basis:

a. Salaries. State shall reimburse Contractor for salary costs, at the following rates, for the actual time of Contractor's personnel in the catagories below while directly engaged in performing work under this contract.

Member of the Technical Advisory Board	$108.00 per day
Project Director and Project Engineer	$ 74.00 per day
Senior Member, Technical Staff	$ 58.40 per day
Member, Technical Staff	$ 48.00 per day
Draftsman	$ 30.40 per day
Final Report Typist	$ 22.00 per day

Said rates are for an eight-hour day; fractions of such eight-hour day shall be reimbursed on a pro rata basis.

b. Indirect Costs and Overhead. State shall pay Contractor an amount equal to 90 percent of the total amount reimbursable under paragraph (a), to cover Contractor's indirect costs and overhead.

c. Profit. State shall pay Contractor, as and for profit, an amount equal to 10 percent of the sum of the total amount reimbusable under paragraphs (a) and (b).

d. Transportation and travel expenses. (1) State agrees to pay (a) actual transportation costs; plus (b) up to $15.00 per day for all other actual expenses within the State of California, including but not limited to meals and

lodging costs. (2) State agrees to pay (a) actual transportation costs; plus (b) actual lodging costs; plus (c) up to $8.50 per day for all other actual expenses outside of the State of California, including but not limited to meals. (3) Such transportation and traveling expenses shall be allowable for Contractor's employees whose time is charged under paragraph (a) and only for travel necessary to the work described in this agreement, away from their headquarters. The headquarters for Contractor's employees is hereby designated as Los Angeles, California.

e. Communication expenses. State shall reimburse Contractor for any long distance telephone, cablegram, telegram and teletype expenses incurred directly pursuant to the prosecution of the work under this contract.

f. Prints and reproductions. State shall reimburse Contractor for the expense of reproducing engineering drawings by either direct or brown-line print, when such reproducing is required by the work hereunder.

g. Consultants. State shall reimburse Contractor for the actual compensation paid to special consultants hired by Contractor to aid in the work required under this contract. No such special consultant shall be hired unless State approves such hiring, and the terms thereof, in writing. The total amount to be paid to Contractor pursuant to this paragraph shall not exceed $6,000.

h. Other direct expenses. State shall reimburse Contractor for any direct, out-of-pocket expenses which are not enumerated above but which are incidental and essential to the work required under this agreement, provided prior approval of State is obtained for each such item of expense in excess of Five Hundred Dollars.

i. Motor-Columbus. State shall pay Contractor, for the account of Motor-Columbus, for work performed by Motor-Columbus personnel, expenses incurred by Motor-Columbus and profit due Motor-Columbus upon the basis of paragraphs (a) to (h) inclusive. For the purposes of paragraph (d), the headquarters for Motor-Columbus employees is hereby designated as Baden, Switzerland.

j. Model Testing Subcontract. State shall reimburse Contractor for all payments made to the model testing firm pursuant to the model testing subcontract together with 10 percent of such payments to reimburse Contractor for its costs of administering said model testing subcontract.

8. Payment for work done under the terms of this agreement shall be made by State periodically as promptly as State procedures will permit after the receipt of itemized invoices in triplicate prepared and submitted monthly by Contractor to the State Department of Water Resources, P. O. Box 388, Sacramento 2, California. Such invoices shall describe the time expended by Contractor's staff and the staff of Motor-Columbus, and actual expenditures incurred and paid, and shall be accompanied by such

copies of invoices, payrolls and other documents and proof as may be required by State to establish such costs as proper under this contract.

9. The amount to be paid Contractor under the terms of this agreement shall not exceed the sum of $450,000, unless pursuant to an amendment hereto signed by Contractor and the Department of Water Resources and approved by the Department of Finance.

10. All work to be accomplished by Contractor pursuant to this agreement shall be completed, and the final report shall be submitted by Contractor to State, within 570 calendar days from the date of this contract.

\- -

FORM 2—APPROVED BY THE ATTORNEY GENERAL (REV. 10-66)
CONTRACTOR—( )
STATE AGENCY—( )
DEPT. OF FINANCE—( )
CONTROLLER—( )

STATE OF CALIFORNIA
STANDARD AGREEMENT

NUMBER 352876
AMENDMENT I.

THIS AGREEMENT, Made and entered into this 14th day of February, 19 64, at Sacramento, County of Sacramento, State of California, by and between State of California, through its duly elected or appointed, qualified and acting

DIRECTOR, (Title of officer acting for State) DEPARTMENT OF WATER RESOURCES (Department or other agency)

hereinafter called the State, and

630.73
31.19

DANIEL, MANN, JOHNSON and MENDENHALL,

hereinafter called the Contractor.

WITNESSETH: That the Contractor for and in consideration of the covenants, conditions, agreements, and stipulations of the State hereinafter expressed, does hereby agree to furnish to the State services and materials, as follows:

(Set forth service to be rendered by Contractor, amount to be paid Contractor, time for performance or completion, and attach plans and specifications, if any.)

That certain Standard Agreement No. 352876, dated July 15, 1963, by and between the parties hereto is hereby amended as follows:

1. Membership of the Technical Advisory Board provided for in the second paragraph of Article 2, page 6, of said agreement is hereby increased from four members to six members by the addition of the services, respectively, of special members Mr. A. H. Church and L. P. Hooper.

2. That Article 7, paragraph (a), page 8, of said agreement is amended to further provide as follows:

Mr. A. H. Church, Special Member
of the Technical Advisory Board..................$150.00 per day

Mr. L. P. Hooper, Special Member
of the Technical Advisory Board..................$150.00 per day

The provisions on the reverse side hereof constitute a part of this agreement. (OVER)

IN WITNESS WHEREOF, This agreement has been executed, in quadruplicate, by and on behalf of the parties hereto, the day and year first above written.

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
(Name of State agency)
(sgd) William E. Warne
By
DIRECTOR OF WATER RESOURCES
Title

DANIEL, MANN, JOHNSON and MENDENHALL
Contractor (a corporation)
(If other than an individual, state whether a corporation, partnership, etc.)
By
Executive Vice President
Title
3325 Wilshire Blvd., Los Angeles 5, Calif.
Address

(Continued on sheets, each bearing name of Contractor)

DO NOT WRITE IN THIS SPACE

FORM | POLICY | BUDGET

Department of General Services
APPROVED
MAY 1 1964
By ROBERT L. HARKNESS, Director
APPROVED BY
For Department of Finance

Disbursement from W.R.R. Fund Item 260 B Ch 1050/63
Reimbursement from CWRDB Fund Item Acc 12,198 Ct 2 Ch 1762/59 Code 439

F.Y.	ACCOUNT NO.		ORGAN NO.	EXP. CODE	BUDGET ITEM NO.	ENCUMBRANCE AMOUNT	UNENC BAL.
64	573	5001	3440	228		20,000.00	160,500.00

I Hereby Certify upon my own personal knowledge that the unencumbered balance of the departmental budget provision for the period stated above is correct.

(After T.B.A. No. ______ or B.R. No. ______)

SIGNATURE OF ACCOUNTING OFFICER 3/25/64 DATE

DWR 627 (REV. 4-62) FUNDING STRIP

THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES

1. The State hereby agrees to pay the services and materials at the times, in t' manner and for the consideration, herein expressed.

2. The Contractor agrees to indemnify and save harmless the State, its officers, agents and employees from any and all claims and losses accruing or resulting to any and all contractors, subcontractors, materialmen, laborers and any other person, firm or corporation furnishing or supplying work, services, materials or supplies in connection with the performance of this contract, and from any and all claims and losses accruing or resulting to any person, firm or corporation who may be injured or damaged by the Contractor in the performance of this contract. The Contractor shall provide necessary workman's compensation insurance at Contractor's own cost and expense.

3. The parties hereto agree that the Contractor, and any agents and employees of Contractor, in the performance of this agreement, shall act in an independent capacity and not as officers or employees or agents of State of California.

4. The State may terminate this agreement and be relieved of the payment of any consideration to Contractor should Contractor fail to perform the covenants herein contained at the time and in the manner herein provided. In the event of such termination the State may proceed with the work in any manner deemed proper by State. The cost to the State shall be deducted from any sum due the Contractor under this agreement, and the balance, if any, shall be paid the Contractor upon demand.

5. This agreement is not assignable by Contractor either in whole or in part.

6. Time is of the essence of each and all the provisions of this agreement, and the provisions of this agreement shall extend to and be binding upon and inure to the benefit of the heirs, executors, administrators, successors, and assigns of the respective parties hereto.

7. It is mutually understood and agreed that no alteration or variation of the terms of this contract shall be valid unless made in writing and signed by the parties hereto, and that no oral understandings or agreements not incorporated herein, and no alterations or variations of the terms hereof unless made in writing between the parties hereto shall be binding on any of the parties hereto.

3. That with respect to reimbursement to Contractor for the services of Mr. A. H. Church and of Mr. L. P. Hooper, paragraphs (b) and (c) of Article 7, page 8, of said agreement shall not be applicable.

4. That the maximum amount expendable under the terms of this agreement is increased from $450,000 to $470,000.........

Except as hereinabove amended, all provisions of said agreement shall continue in full force and effect. ....

BUDGET DIVISION
MAR 31 1964
DEPARTMENT OF FINANCE

1964 APR 10 PM 3 10

DEPARTMENT OF
WATER RESOURCES
SACRAMENTO

FORM 2—APPROVED BY THE ATTORNEY GENERAL (REV. 10-56)

CONTRACTOR—( )
STATE AGENCY—( )
DEPT. OF FINANCE—( )
CONTROLLER—( )

STATE OF CALIFORNIA
STANDARD AGREEMENT

PLEASE INITIAL

NUMBER 352876
AMENDMENT II.

THIS AGREEMENT, Made and entered into this 5th day of May, 19 64, at Sacramento, County of Sacramento, State of California, by and between State of California, through its duly elected or appointed, qualified and acting

DIRECTOR, (Title of officer acting for State) DEPARTMENT OF WATER RESOURCES (Department or other agency)

hereinafter called the State, and

DANIEL, MANN, JOHNSON AND MENDENHALL,

hereinafter called the Contractor.

WITNESSETH: That the Contractor for and in consideration of the covenants, conditions, agreements, and stipulations of the State hereinafter expressed, does hereby agree to furnish to the State services and materials, as follows:

(Set forth service to be rendered by Contractor, amount to be paid Contractor, time for performance or completion, and attach plans and specifications, if any.)

That certain Standard Agreement No. 352876 dated July 15, 1963, as amended by Amendment I thereto, dated February 14, 1964, by and between the parties hereto is hereby further amended as follows:

1. Sections 1.c., d. and 7.j. are amended by inserting the words "firms", "contracts", "institutions" and "subcontracts" for the words "firm", "contract", "institution" and "subcontract" wherever such words appear in said Sections.

2. The third and fourth sentences of Section 1.d. are hereby deleted and the following sentences inserted in place thereof: "Contractor shall establish a resident office at each test laboratory location and qualified personnel of Motor-Columbus, Ltd., or Contractor assigned to the project shall witness all tests." "Reports on the progress of model testing shall be furnished to State twice monthly".

3. The second paragraph of Section 2 is amended by deleting the name of "Mr. L. H. Kessler" and inserting in place thereof the name "Mr. Hans Gartmann".

(CONT'D)

The provisions on the reverse side hereof constitute a part of this agreement.

IN WITNESS WHEREOF, This agreement has been executed, in quadruplicate, by and on behalf of the parties hereto, the day and year first above written.

STATE OF CALIFORNIA	DANIEL, MANN, JOHNSON AND MENDENHALL
DEPARTMENT OF WATER RESOURCES (Name of State agency)	Contractor (a corporation) (If other than an individual, state whether a corporation, partnership, etc.)
By Wesley Gardner	By Stanley A. Moe
	Stanley A. Moe
DEPUTY Director (Title)	Executive Vice President (Title)
	3325 Wilshire Blvd., Los Angeles 5, Calif. (Address)

DWR

DO NOT WRITE IN THIS SPACE

Disbursement from W.R.R. Fund Item 266 B Ch. 1050/63

Reimbursement from Various Fund Item — Ch — Code 707

FORM | POLICY | BUDGET

Department of General Services
APPROVED
JUN 11 1964
Robert L. Harkness
ROBERT L. HARKNESS,
APPROVED BY
Department of Finance

F.Y.	ACCOUNT NO.		ORGAN. NO.	EXP. CODE	BUDGET ITEM NO	ENCUMBRANCE	UNENC. BAL.
64	573	5001	3440	228		65000.00	0

I Hereby Certify upon my own personal knowledge that the unencumbered balance of the departmental budget provision for the period stated above is correct.

(After T.B.A. No. ______ or B.R. No. ______)

DWR 627 (REV. 4-63) FUNDING STRIP

SIGNATURE OF ACCOUNTING OFFICER — DATE 5/7/64

THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES

(After T.B.A. No. ______ or B.R. No. ______)

DWR 627 (REV. 4-63) FUNDING STRIP

SIGNATURE OF ACCOUNTING OFFICER — DATE

THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES

1. The State hereby agrees to pay for the services and materials at the times, in the manner and for the considerati herein expressed.

2. The Contractor agrees to indemnify and save harmless the State, its officers, agents and employees from any and a claims and losses accruing or resulting to any and all contractors, subcontractors, materialmen, laborers and any othe person, firm or corporation furnishing or supplying work, services, materials or supplies in connection with the performanc of this contract, and from any and all claims and losses accruing or resulting to any person, firm or corporation who ma be injured or damaged by the Contractor in the performance of this contract. The Contractor shall provide necessar workman's compensation insurance at Contractor's own cost and expense.

3. The parties hereto agree that the Contractor, and any agents and employees of Contractor, in the performance of thi agreement, shall act in an independent capacity and not as officers or employees or agents of State of California.

4. The State may terminate this agreement and be relieved of the payment of any consideration to Contractor shoul Contractor fail to perform the covenants herein contained at the time and in the manner herein provided. In the event o such termination the State may proceed with the work in any manner deemed proper by State. The cost to the State sha be deducted from any sum due the Contractor under this agreement, and the balance, if any, shall be paid the Contracto upon demand.

5. This agreement is not assignable by Contractor either in whole or in part.

6. Time is of the essence of each and all the provisions of this agreement, and the provisions of this agreement shall exten to and be binding upon and inure to the benefit of the heirs, executors, administrators, successors, and assigns of th respective parties hereto.

7. It is mutually understood and agreed that no alteration or variation of the terms of this contract shall be valid unles made in writing and signed by the parties hereto, and that no oral understandings or agreements not incorporated herein and no alterations or variations of the terms hereof unless made in writing between the parties hereto shall be binding o any of the parties hereto.

4. Section 3 is amended by adding, after the last sentence thereof, the following: "The Contractor agrees to pay for transportation and travel expenses, in accordance wit Section 7.d.(1) and (2) hereof, for a maximum of four inspection trips by State personn of the model testing firms and testing progress. The State shall designate to the Contractor in writing the personnel to make such inspections and the schedule of same".

5. Section 7.g. is amended to increase the amount the Contractor shall be reimbursed for payments to consultants from not to exceed $6,000 to not to exceed $21,600.

6. Section 7, is further amended by inserting subparagraph k. as set forth below:

"k. The Salaries and Indirect Cost and Overhead rates as set forth in subparagraphs a. and b., respectively, shall be binding on the parties during the fiscal y commencing July 1, 1964, through June 30, 1965, and said rates shall be negotiated by t parties for each such fiscal year thereto succeeding. Salaries shall be adjusted to co form as nearly as possible to the latest publication of the State Personnel Board's Cooperative Wage and Salary Survey in Los Angeles County."

7. Subsection 7.d.(1) is hereby deleted in its entirety and the following subsection 7.d(1) inserted in place thereof:

"Section 7.d.(1). State agrees to pay (a) actual transportation costs; plus (b) $15 per day for all other expenses, including but not limited to meals and lodgings

8. Section 9 is amended to increase the total amount to be paid to the Contractor from not to exceed $470,000 to not to exceed $1,145,000.

9. Section 10 is hereby deleted in its entirety and the following Section 10 inser in place thereof:

"Section 10. The Contractor shall submit the final report, as set forth in Section 1.f. hereof, to a commercial printing vendor or Contractor's printing faciliti on or before the expiration of 930 days from the date of the contract and all services required to be performed by the Contractor shall be completed on or before May 30, 1966. The target date for submission by Contractor of Preliminary Report on Efficiency and Reliability Complete is and shall be January 15, 1965."

10. Except as herein amended all terms and conditions of the contract as previously amended shall continue in full force and effect.

State of California
THE RESOURCES AGENCY
Department of Water Resources

REPORT ON ALTERNATIVE LOCATIONS OF TEHACHAPI LIFT SYSTEM

APRIL 1965

HUGO FISHER
Administrator
The Resources Agency

EDMUND G. BROWN
Governor
State of California

WILLIAM E. WARNE
Director
Department of Water Resources

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The Resources Agency
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CHAPTER I. INTRODUCTION

Since inception of work on the California Aqueduct Project in 1950, plans for effecting the required pumping lift at the north slopes of the Tehachapi Mountains have been subjected to nearly continuous, and progressively more detailed, reevaluations. These reevaluations were required by, and have kept pace with, the development of more refined data on construction materials and methods, advances in design of turbo machinery and motors, more accurate identification of geologic conditions based on continuing geologic exploration programs, determinations of potential power sources, updated projections of power costs, studies of the market for power, and investigations of methods of operation.

In addition to the Department of Water Resources, other agencies contributed importantly to this work. Among these are The Metropolitan Water District of Southern California which, by virtue of being the largest contractor for California Aqueduct Project water, maintains an eminent interest in the Tehachapi pumping lift, and the Bechtel Corporation of San Francisco which has been retained on separate occasions by both the Department and the Metropolitan Water District to investigate the Tehachapi pumping lift.

During the course of investigations on the Tehachapi Pumping Plant, engineering reports were issued at frequent intervals to record progress thereon.* The most recent of these are the Department's report of September 1964, entitled "Technical and Economic Feasibility of Single-Lift, Two-Lift and Three-Lift Systems, Tehachapi Pumping Plant", and the Bechtel Corporation's report of September 1964, entitled "Alternative Schemes for the Tehachapi Crossing of the California State Water Project." The Metropolitan Water District of Southern California sponsored the latter report.

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*See Bibliography in Appendix A

In the foregoing named Department's report of September 1964, emphasis was given to alternative plans for effecting the Tehachapi pumping lift. All of these alternatives were aligned on a ridge about one mile easterly of Pastoria Creek. This ridge was selected, primarily, because it offers adequate foundation rock and because it provides the most abrupt rise from the floor of the San Joaquin Valley at elevation 1,239 feet where the pump lift commences to the Tehachapi Crossing elevation which has been established at 3,165 feet.

This report is supplemental to that of September 1964 and expands the study area for siting Tehachapi pumping lift facilities to include Pastoria Canyon. The alternatives selected were those deemed most favorable based upon the results of prior studies.

Objective and Scope

This report has the objective of presenting the results of a reconnaissance study on the engineering and geologic feasibility of two-lift systems located in Pastoria Canyon and single- and two-lift systems located on an alignment approximately one mile northeast of Pastoria Canyon, hereafter called the Ridge alignment. It is not intended to be a preliminary design report.

The results of this investigation, together with the results of studies of pumping equipment conducted by Daniel, Mann, Johnson and Mendenhall, consultants to the Department, will provide the data necessary for determining the lift system portion of the Tehachapi Crossing.

The reach of aqueduct included in the study begins at the mouth of Pastoria Canyon and terminates at the north portal of the Carley V. Porter Tunnel in Beartrap Canyon in the Tehachapi Mountains. Engineering investigation

including cost estimates on single- and two-lift systems superimposed on two alignments were made.

Geologic studies, consisting of surficial geologic mapping and subsurface exploration, were concentrated on features which were part of two-lift systems. This was done in order to update the knowledge on the geology and foundation conditions associated with two-lift systems, particularly the systems located in Pastoria Canyon, to that of the single-lift systems on the Ridge. Because exploration of single-lift systems is under continuous investigation by the Department and the data collected are voluminous, it is not within the scope of this report to present a detailed analysis of this work. This report will, however, include the results of these studies.

A complete report on the geologic investigation will be published at a later date.

Prior Investigations

The first definitive report touching on the Tehachapi lift is the State Water Resources Board report, "Feasibility of Feather River Project and Sacramento-San Joaquin Delta Diversion Projects Proposed as Features of the California Water Plan", dated May 1951. This report contemplated the use of a series of six pumping plants on the alignment in Pastoria Canyon.

In 1952, a more thorough investigation of the Tehachapi Pumping Plant was initiated, the results of which are summarized in the Division of Water Resources report, "Program for Financing and Constructing the Feather River Project as an Initial Unit of the California Water Plan", dated February 1955. This report introduced the concept of a single pumping plant located in Pastoria Canyon.

In 1955, the Bechtel Corporation was employed to make an independent review of the State's 1955 report of the water project. Its report recommended that studies be made of the use of multiple-stage, as well as the single-stage pumps in series, for this lift.

Between 1956 and 1959, further investigations were made of this portion of the aqueduct system. The results were published in Department of Water Resources Bulletin No. 78, "Investigation of Alternative Aqueduct Systems to Serve Southern California", dated December 1959. This report presented a single pumping plant, situated at the base of a ridge one mile east of Pastoria Canyon, which accomplished the pump lift through steam driven single-stage pumps arranged in series.

This was the system reviewed by the Chas. T. Main Corporation which, in its report of October 1960, entitled "General Evaluation of the Proposed Program for Financing and Constructing the State Water Resources Development System of the State of California Department of Water Resources", endorsed in general the State's engineering concept.

After publication of Bulletin No. 78, further studies were conducted to provide more refined technical and economic comparisons of single- and multiple-lift systems. The results of these studies are summarized in Department of Water Resources report, "Preliminary Design and Economic Evaluation of Tehachapi Single-Lift and Multilift Pumping Schemes", dated December 1963. In this report, alternative alignments were considered that were located both in Pastoria Canyon and on the Ridge as presented in Bulletin No. 78.

In February 1964, studies of multilift and single-lift systems located on the Bulletin No. 78 Ridge alignment were reinitiated and results recorded in the Department's report of September 1964, "Technical and

Economic Feasibility of Single-Lift, Two-Lift, and Three-Lift Systems, Tehachapi Pumping Plant." Upon conclusion of work on that report, the work recorded herein was initiated.

Concurrently with the Department's work that culminated with the September 1964 report and this report, the Bechtel Corporation of San Francisco, under the sponsorship of The Metropolitan Water District of Southern California, pursued separate paralleling investigations. During the course of these investigations, there was free exchange of data between Bechtel and the Department. The Bechtel Corporation's report of September 1964 records progress on its investigation to that date. Bechtel plans to complete a report on its subsequent investigations early in May 1965.

Alternatives Included in Report

In all, six lift systems were investigated and are included in this report. They consist of two single-lift systems, and four two-lift systems. These systems are superimposed on two general alignments with one, a two-lift system, combining the two alignments. Economic comparisons and geologic investigations were conducted on the six alternatives.

System 1, called the Pastoria Two Equal Lift, is located entirely along Pastoria Canyon. A dam and reservoir at the second lift is located at an elevation which provides equal static lifts. System 2, the Pastoria Two Lift, is also located entirely along Pastoria Canyon. A dam and reservoir at the second lift is upstream (at a higher elevation in the canyon) of that in System 1, thus providing unequal lifts. System 3, Ridge-Pastoria Two Lift, combines the two alignments and locates the first lift on the Ridge and the second lift at the same site as System 2.

System 4, Ridge Two Equal Lift, is located entirely along the Ridge alignment with an off-line dam and reservoir at the second lift in the small canyon to the east of the Ridge. Systems 5 and 6, Ridge Single Lift with Underground and Surface Discharge Lines, respectively, are located along the Ridge alignment.

Exploration of the features of the alternative systems as of April 23, 1965, consisted of 25 dozer trenches, 17 diamond drill holes, 12 bucket auger holes, and a comprehensive geophysical exploration program. The alternative damsites and the plant sites were studied in considerable detail, while the remaining features of the systems were investigated largely by surficial exploration. Exploration of potential borrow areas began on April 26, 1965; however, the information obtained was not available at the time of this writing.

The location and description of exploration with respect to various features of the systems are presented in tabular form as follows:

Feature	Diamond Drill Holes		Trenches	Other
Station A Pumping Plant, Systems 1 and 2	PP- 1	124.7 ft.	3	1 bucket auger hole
	PP- 2	109.3 ft.		7 seismic lines
	PP- 3	200.2 ft.		Magnetometer exploration
	Total	434.2 ft.		
Equal Lift Damsite System 1	DDH- 1	81.0 ft.	7	2 access roads
	DDH- 2	151.2 ft.		6 seismic lines
	DDH- 4	244.5 ft.		
	DDH- 5	107.3 ft.		
	DDH- 6	85.0 ft.		
	DDH-11	130.0 ft.		
	DDH-12	96.0 ft.		
	DDH-13	20.0 ft. (still in progress)		
	DDH-14	20.0 ft. (still in progress)		
	Total	935.0 ft. plus		
Unequal Lift Damsite	DDH- 3	80.5 ft.	2	3 seismic lines
	DDH- 7	98.0 ft.		
	DDH- 9	75.5 ft.		
	Total	254.0 ft.		
Station B Pumping Plant, System 1	DDH- 8	180.0 ft.	2	1 seismic line
	DDH-10	130.0 ft.		
	Total	310.0 ft.		
Station B Pumping Plant, Systems 2 and 3	None		1	None
Off-Line Damsite, System 4	DH- 1	131.0 ft.	2	None
	DH- 2	140.0 ft.		
	Total	271.0 ft.		
Station B Pumping Plant, System 4	DH-65	1420.0 ft.	2	1 access road

Total footage, diamond drill (not including DH-65) January - April 1965 2,204.02 ft.

CHAPTER II. CONCLUSIONS AND RECOMMENDATIONS

Conclusions

As a result of the investigations of the six alternative systems for the Tehachapi lift reported herein, the following conclusions are drawn:

1. The total estimated present worth of all costs, both capital and annual, of five of the six systems studied appear to be essentially equal. The remaining system studied (System 3, Ridge-Pastoria Two-Lift) is significantly higher in cost.

2. Geologic investigations of the proposed damsites in Pastoria Canyon and System 1 (Pastoria Two-Equal Lift) Station B pumping plant site have revealed serious foundation defects which make it imprudent to construct a lift system in this canyon. In addition, the steep topography and the presence of existing slides in Pastoria Canyon indicate that landslides or rock falls, generated by seismic activity, could block any reservoirs and render them useless as well as damage or destroy pumping plants, discharge lines or other facilities located in Pastoria Canyon.

3. Engineering and geologic investigations of the features of the lift systems located entirely along the Ridge alignment verify the feasibility and reliability of such systems.

4. A high degree of risk would be involved in the construction of a conveyance system in Pastoria Canyon due to the existence of extremely poor geologic conditions and steep topography in this area of high seismic potential. A conveyance system constructed along the Ridge alignment would have a much lower degree of risk because of good foundation conditions and a minimum exposure to landslides and rock falls in this same area of high seismic potential.

RECOMMENDATIONS

In view of the foregoing conclusions and the conclusions in the report of Daniel, Mann, Johnson, and Mendenhall entitled "Tehachapi Pumping Facility, California State Water Project, Research and Development Program", dated April 1965, the following recommendations are made:

1. Abandon any further consideration of pump lift schemes involving construction of facilities partially or entirely in the Pastoria Canyon.

2. Proceed immediately with design of a system along the Ridge Route (System 4, Ridge Two-Lift, System 5, Ridge Single-Lift with Underground Penstocks, or System 6, Ridge Single-Lift with Surface Penstocks).

3. Decide upon either surface or underground penstocks as a result of early design studies, giving due weight to the recommendations of the Consulting Board for Earthquake Analysis.

4. Complete the investigation of the damsite to be utilized for System 4.

CHAPTER III. CONDUCT OF STUDIES

Criteria and Guidelines

The engineering evaluation of the alternative systems was made with respect to the criteria as given in the following paragraphs, and on the basis of the specific features discussed in subsequent sections of this chapter.

Operational Scheme

The lift system is to be operated initially using offpeak power until all pumping units are installed, after which it will phase into continuous operation. The ultimate continuous discharge is 2,594,900 acre-feet per year, or a continuous flow of 4,093 cubic feet per second.

The delivery discharge buildup and corresponding staging of pump installation which was used for this report is as follows:

Year	Total delivery requirements in thousands of acre-feet*	Total delivery requirements in cfs*	Number of installed units single lift	Number of installed units two lift
1971	390.7	818	6	4
72	711.2	1,295	9	6
73	973.7	1,685	12	7
74	967.7	1,676	12	7
75	890.2	1,561	12	7
76	1,019.6	1,753	12	7
77	1,132.3	1,920	14	8
78	1,260.5	2,111		
79	1,381.3	2,290		
80	1,501.3	2,468		
81	1,623.6	2,650		
82	1,743.3	2,828		
83	1,864.0	3,007		
84	1,982.7	3,183		
85	2,102.1	3,360		
86	2,225.3	3,543		
87	2,352.9	3,733		
88	2,481.8	3,925		
89	2,560.3	4,042		
90	2,588.1	4,083		
91	2,594.9	4,093		

*Includes reservoir filling from 1971 to 1974

This discharge buildup corresponds to the Department's contractual obligations for delivery of project water. Earlier studies of the Tehachapi Lift were based on estimated discharge of 5,000 cubic feet per second, which represented a necessarily conservative estimate made prior to the completion of project water contract negotiations.

Power and Energy Rates

The rates are in accordance with the Power Schedule No. 3A as given in Table III-1.

Maximum Size and Type of Pumping Unit

A maximum unit size of 75,000 horsepower was used in determining the number of units for each system. The number of units selected on the basis of this limitation is 14 units for the single-lift systems and 8 units per plant for the two-lift systems. The type of pump used is: a four-stage, single suction pump for the single-lift systems, and a two-stage, double flow pump for the two-lift systems.

System Storage

A forebay is provided at the intake of the first station of all systems. This forebay has a capacity of 340 acre-feet which is the volume necessary to supply the plant at a sustained rate of 4,093 cubic feet per second for a period of 30 minutes, plus the volume required to impound inflow for 30 minutes at the same rate.

For the two-lift systems, a reservoir with a usable capacity of 170 acre-feet is provided at the intake to the second lift.

TABLE III-1

POWER SCHEDULE NO. 3A

Year	Capacity* continuous $/kw/yr	Energy** continuous mills/kwh	Energy offpeak mills/kwh	Year	Capacity* continuous $/kw/yr	Energy** continuous mills/kwh	Energy offpeak mills/kwh
1971	17.50	2.40	2.60	1992	15.70	1.50	1.60
72	17.50	2.30	2.50	93	15.30	1.48	1.56
73	17.10	2.26	2.46	94	15.30	1.46	1.52
74	17.10	2.22	2.42	95	15.30	1.44	1.48
75	17.10	2.18	2.38	96	15.30	1.42	1.44
76	17.10	2.14	2.34	97	15.30	1.40	1.40
77	17.10	2.10	2.30	98	14.30	1.38	1.38
78	16.90	2.04	2.24	99	14.30	1.36	1.36
79	16.90	1.98	2.18	2000	14.30	1.34	1.34
80	16.90	1.92	2.12	01	14.30	1.32	1.32
81	16.90	1.86	2.06	02	14.30	1.30	1.30
82	16.90	1.80	2.00	03	13.90	1.30	1.28
83	16.40	1.76	1.96	04	13.90	1.30	1.26
84	16.40	1.72	1.92	05	13.90	1.30	1.24
85	16.40	1.68	1.88	06	13.90	1.30	1.22
86	16.40	1.64	1.84	07	13.90	1.30	1.20
87	16.40	1.60	1.80				
88	15.70	1.58	1.76				
89	15.70	1.56	1.72				
90	15.70	1.54	1.68	No Offpeak Capacity Cost			
91	15.70	1.52	1.64	Transmission Charge $753,000/yr			

*Based on maximum demand of year.
**For all energy up to kw x 8,760.

Description of Engineering Features

During the course of these studies, six systems for the conveyance of water from a point northwest of the mouth of Pastoria Canyon to the north portal of the Carley V. Porter Tunnel were investigated, and are presented here for comparison.

System 1, Pastoria Two-Equal Lift, which is shown on Plate 3, begins at the upstream common point, located northwest of the mouth of Pastoria Canyon. The aqueduct flow is conveyed by a siphon and open canal, for a total length of 3,500 feet, to the first pumping plant with an intake water surface elevation of 1,239 feet. This plant, containing eight units, is located in the mouth of Pastoria Canyon and has a forebay at the intake. A manifold connects the eight units with two surface discharge lines, each 4,250 feet long and 13 feet in diameter. These lines rise southeasterly along the ridge and convey the water to a combination gatehouse and surge tank located at a tunnel portal. This tunnel, 23.5 feet in diameter, runs southeasterly for a length of 10,225 feet, discharging into a reservoir in Pastoria Canyon. The location of this reservoir is such that the static head at each plant is equal, which results in an operating water surface elevation at the reservoir of 2,195 feet. A second pumping plant, also containing eight units, is located on the west side of the Pastoria Canyon adjacent to the reservoir. A manifold connects the eight units with two discharge lines, each 1,620 feet long and 13.5 feet in diameter. These lines rise in a southerly direction to convey the water to a combination gatehouse and surge tank at a tunnel portal. A combination of two tunnels, each 23.5 feet in diameter, and two siphons, in series, connect the surge tank to the north portal of the Carley V. Porter Tunnel, the downstream common point of all systems. The hydraulic grade line elevation at this point is 3,150.

System 2, Pastoria Two Lift, as shown on Plate 4, is identical to System 1 from the upstream common point to Station A pumping plant. From this plant, two discharge lines, each 4,160 feet long and 13 feet in diameter, rise along a ridge in a southeasterly direction and convey the water to a combination gatehouse and surge tank at a tunnel portal. This tunnel, 23.5 feet in diameter, is aligned southeasterly for a distance of 12,336 feet, and discharges into a reservoir in Pastoria Canyon. This reservoir is higher than the reservoir in the equal lift system, thereby providing unequal lifts. The operating water surface elevation of the reservoir is 2,320 feet. A second pumping plant with eight units is located on the south side of and adjacent to the reservoir. A manifold connects the eight units with two discharge lines, each 2,185 feet long and 13.5 feet in diameter. These lines rise along a ridge in a southeasterly direction, conveying the water to a combination gatehouse and surge tank. The surge tank is then connected to a tunnel portal by 900 feet of 23.5-foot diameter cast-in-place pipe. The tunnel, 23.5 feet in diameter, then trends southeasterly for a length of 7,125 feet, to a siphon which is 23.5 feet in diameter and 152 feet long. This siphon then connects to the north portal of the Carley V. Porter Tunnel.

System 3, Ridge-Pastoria Two Lift, is shown on Plate 5. Beginning at the upstream common point, the aqueduct flow is conveyed by a siphon easterly across Pastoria Creek and then by open canal northeasterly for a total length of 7,440 feet to the station A pumping plant. This pumping plant, which contains eight units, is located approximately 1 mile northeast of Pastoria Canyon. The normal water surface elevation in the canal at the intake is 1,239 feet. An off-line forebay is located at the intake to the

plant. A manifold connects the eight units to two discharge lines, each 4,170 feet long and 13.5 feet in diameter. These lines rise southeasterly along the ridge conveying the water to a combination gatehouse and surge tank at a tunnel portal. This tunnel, 23.5 feet in diameter, runs southeasterly for a length of 13,065 feet, discharging into the reservoir in Pastoria Creek identical to that in the Pastoria Two Lift System. From this reservoir, water is conveyed to the downstream common point at the Carley V. Porter Tunnel by the same system as described for the Pastoria Two Lift System.

System 4, Ridge Two-Equal Lift, is shown on Plate 6. The approach conveyance from the upstream common point to Station A pumping plant is identical to that described in the Ridge-Pastoria Two Lift. From the plant, a manifold connects the eight pumping units with two discharge lines, each 3,670 feet long, and 13.5 feet in diameter. The lines rise southeasterly along the ridge to a combination gatehouse and surge tank located at the intake to Station B. An off-line reservoir is located in the canyon approximately 2,000 feet to the east of the pumping plant and is joined to the surge tank by a tunnel, 25 feet in diameter, and 1,950 feet in length. An intake manifold connects the surge tank to the eight units in the pumping plant. From the pumping plant, a discharge manifold connects the units to two discharge lines, each 4,340 feet in length, and 13.5 feet in diameter. These lines rise in a southeasterly direction to a combination gatehouse and surge tank located at the north portal of a tunnel. The flow is then conveyed through a series of tunnels, 23.5 feet in diameter, and siphons for a distance of 19,352 feet, in a southeasterly direction, to the north portal of the Carley V. Porter Tunnel.

System 5, Ridge Single Lift Underground, is shown on Plate 7. From the common point in Pastoria Canyon, the approach conveyance facilities are identical to Ridge-Pastoria Two Lift. The pumping plant at the base of the ridge contains 14 units. A manifold connects the 14 units with two discharge tunnels, 7,420 feet long and 12 feet in diameter. The tunnels rise in two steps in a southeasterly direction and join to two surface pipelines, each 12 feet in diameter and 850 feet long, which terminate at a gatehouse and surge tank at a tunnel portal. The flow is then conveyed through the same series of tunnels and siphons as that in the Ridge Two-Equal Lift System, which terminate at the north portal of the Carley V. Porter Tunnel.

System 6, Ridge Single Lift Surface, is shown on Plate 8. This system is identical to the Ridge Single Lift Underground except the discharge lines are entirely on the ground surface. The discharge lines are 12.5 feet in diameter and 7,950 feet long. To eliminate downsurge problems, the surge tank is located approximately 1,000 feet up-aqueduct from the tunnel portal.

Table III-2, page III-8 lists the pertinent engineering data on the features of all the systems.

TABLE III-2

PERTINENT ENGINEERING DATA

SYSTEM NUMBER ‡	1	2	3	4	5	6
Number of Lifts	2-Equal	2	2	2-Equal	1	1
Route						
First Lift	Pastoria	Pastoria	Ridge	Ridge	Ridge	Ridge
Second Lift	Pastoria	Pastoria	Pastoria	Ridge	-	-
Design Discharge ; cfs	4,093	4,093	4,093	4,093	4,093	4,093
Forebay						
Maximum Operating W.S.El.; ft	1,239	1,239	1,239	1,239	1,239	1,239
Normal Operating W.S.El.; ft	1,234	1,234	1,234	1,234	1,234	1,234
Minimum Operating W.S.El.; ft	1,229	1,229	1,229	1,229	1,229	1,229
Surface Area - Max. O.W.S.El.; acres	35	35	38.4	38.4	38.4	38.4
Storage Capacity; af	450	450	372	372	372	372
Pumping Plant No. 1						
Number of Units	8	8	8	8	14	14
Type of Pump	2-Stage DF	2-Stage DF	2-Stage DF	2-Stage DF	4-Stage SS	4-Stage SS
Capacity Per Unit; cfs	511.6	511.6	511.6	511.6	292.4	292.4
Speed; rpm	600	600	600	600	600	600
Horsepower Per Unit	62,700	71,120	70,600	62,300	72,200	71,900
N_s - Specific Speed	1,930	1,760	1,770	1,940	2,070	2,080
Z - Submergence (Norm. Flow); ft	58	57	57	57	66	66
* Z_{mf} - Submergence (Min. Flow); ft	62	61	61	61	71	71
Expected Efficiency (B.E.P.); %	92.10	91.70	91.72	92.11	91.10	91.10
Pumping Plant No. 2						
Number of Units	8	8	8	8		
Type of Pump	2-Stage DF	2-Stage DF	2-Stage DF	2-Stage DF		
Capacity Per Unit; cfs	511.6	511.6	511.6	511.6		
Speed; rpm	600	514	514	600		
Horsepower Per Unit	62,000	54,200	54,200	62,300		
N_s - Specific Speed	1,950	1,850	1,850	1,940		
Z - Submergence (Norm. Flow); ft	57	41	41	57		
* Z_{mf} - Submergence (Min. Flow); ft	69	56	56	75		
Expected Efficiency (B.E.P.); %	92.12	91.85	91.85	92.11		
Discharge Lines Lift No. 1						
Type	Surface	Surface	Surface	Surface	Surf.&Undgrd.	Surface
Number of Pipes	2	2	2	2	2	2
Pipe Diameter; ft	13.0	13.0	13.5	13.5	12.0	12.5
Maximum Steel Thickness; in.						
A - 517	1	$1\frac{1}{4}$	1	1	-	2
A - 441	-	-	-	-	2 13/16	$\frac{1}{2}$
Length; ft	4,250	4,610	4,170	3,670	8,270	7,950
Discharge Lines Lift No. 2						
Type	Surface	Surface	Surface	Surface		
Number of Pipes	2	2	2	2		
Pipe Diameter; ft	13.5	13.5	13.5	13.5		
Maximum Steel Thickness; in.						
A - 517	1	3/4	3/4	1		
A - 441	-	-	-	-		
Length; ft	1,620	2,185	2,185	4,330		

SYSTEM NUMBER ‡	1	2	3	4	5	6
Tunnels						
Number	3	2	2	3	3	3
Diameter; ft	23.5	23.5	23.5	23.5	23.5	23.5
Total Length; ft	18,465	19,461	20,190	16,803	16,803	16,803
Siphons						
Number	2	2	2	3	3	3
Total Length; ft	3,930	1,052	1,052	2,593	2,593	2,593
Reservoir						
Maximum Operating W.S.El.; ft	2,200	2,328	2,328	2,217		
Normal Operating W.S.El.; ft	2,195	2,320	2,320	2,204		
Minimum Operating W.S.El.; ft	2,190	2,310	2,310	2,187		
Active Storage; af	170	170	170	170		
Type of Dam	Earthfill	Earthfill	Earthfill	Earthfill		
Maximum Height of Dam; ft	122	120	120	167		
Length of Dam; ft	660	580	580	660		
Total Volume of Embankment; cy	1,131,000	825,000	825,000	922,000		
Volume of Impervious Fill; cy	320,000	267,000	267,000	226,000		
Spillway Type	Glory	Glory	Glory	Glory		
Spillway Capacity; cfs	7,300	6,700	6,700	4,100		
Hydraulic Data						
First Lift						
H.G.L. El. at D.S. End of Lift; ft	2,195	2,320	2,320	2,204.1	3,150	3,150
H.G.L. El. at Plant Intake; ft	1,239	1,239	1,239	1,239	1,239	1,239
Difference in Elevation; ft	956	1,081	1,081	965.1	1,911	1,911
Total Head Loss for Lift; ft	39.4	42.5	34.8	23.0	72.2	63.5
Dynamic Head for Lift; ft	995.4	1,123.5	1,115.8	988.1	1,983.2	1,974.5
Second Lift						
H.G.L. El. at D.S. End of Lift; ft	3,150	3,150	3,150	3,150		
H.G.L. El. at Plant Intake; ft	2,195	2,320	2,320	2,204.1		
Difference in Elevation; ft	955	830	830	945.9		
Total Head Loss for Lift; ft	28.6	27.4	27.4	42.2		
Dynamic Head for Lift; ft	983.6	857.4	857.4	988.1		
Total Head Loss for System; ft	68.0	69.9	62.2	65.2	72.2	63.5
Total Dynamic Head of System; ft	1,979.0	1,980.9	1,973.2	1,976.2	1,983.2	1,974.5

‡ System 1 Pastoria Two-Equal Lift
System 2 Pastoria Two Lift
System 3 Ridge-Pastoria Two Lift
System 4 Ridge Two-Equal Lift
System 5 Ridge Single Lift with Underground Discharge Lines
System 6 Ridge Single Lift with Surface Discharge Lines

* This value used for cost estimating purposes.

1. Submergence is measured from Normal Operating Water Surface of the pump intake to ℄ of:
   - A The upper first stage impeller of the 2-Stage DF Pumps.
   - B The impeller of the first stage of the 4-Stage SS Pumps.
2. Mannings "n" of 0.012 was used in the hydraulic computations for steel discharge lines.
3. Mannings "n" of 0.014 was used in the hydraulic computations for concrete lined tunnels.

Geology

A detailed description of the results of the geologic exploration associated with the two-lift systems is given in the following paragraphs. In addition, a summary report of the continuing exploration along the Ridge alignment is given in succeeding paragraphs.

Pastoria Canyon Alignments

Forebay. The forebay site is located at the edge of the San Joaquin Valley on the east side of the mouth of Pastoria Canyon. The bulk of the forebay excavation will be in recent alluvium with minor portions in the Tertiary volcanics and Tecuya formation.

The alluvium consists of unconsolidated gravelly sand with large boulders up to three feet in diameter. The alluvium reaches a maximum depth of 85 feet in the forebay area. A major part of the reservoir floor will be in this unit (See Plate No. 19). The depth to water was estimated to be 65 feet, which was determined from drilling at the pumping plant site.

Preliminary soil test data based on a single bucket auger hole indicate that the alluvium will be at least semipervious, and a lining for the reservoir will be required.

Tertiary volcanics consist of extensively fractured and locally brecciated flows, and will also require a lining to prevent excessive seepage losses. The sandstone and conglomerate of the Tecuya formation appear to be relatively impervious; however, testing of this material is required to determine its permeability characteristics.

The entire forebay excavation will be accomplished by common excavation methods. The presence of large boulders in the alluvium will require

the use of draglines or shovels for the major part of the excavation. Volcanics and units of the Tecuya formation will require ripping prior to removal.

Slopes of 2:1 with benches at 40-foot intervals, are recommended for the forebay excavation.

Station A Pumping Plant. Station A Pumping Plant will require an excavation to a depth of approximately 150 feet. The site is underlain by deep, unconsolidated alluvium which overlies poorly consolidated sandstone and conglomerate of the Tecuya formation. The site was explored by three diamond drill holes and an extensive geophysical survey. The alluvium reaches a maximum known depth of 64 feet and an interpreted depth of 85 feet near the northwest edge of the excavation. The foundation of the pumping plant will rest entirely on sandstone and conglomerate of Tecuya formation. The Tecuya strata have a strike of N25E, and an average NW dip of 25 to 35 degrees, as interpreted from outcrop and drill hole data. The bedding is dipping into the deepest part of the excavation and could create a potential slide hazard on the south face of the plant excavation. The Tecuya units are generally light grey to greenish in color and range from coarse arkosic sandstone to conglomerate containing well rounded pebbles. All units are overall very poorly cemented and appear to weaken considerably when saturated. Samples obtained from drill holes below the water table were very weak (can be broken with slight finger pressure), while similar material in near surface trenches was hard enough to require ripping. The cementing matrix is generally nonplastic and consists of fine sand and silt with very little clay. Occasional hard interbeds containing caliche and thin clay seams were cored, but are generally very thin and unimportant. Traces of possible

clayey gouge and several slickensided surfaces were found in drill hole PP-2. These shear zones appear to be less than one foot wide and are not expected to influence the stability of the excavation or the foundation of the plant. No major faults were observed in the exploration for the pumping plant.

The water table measured during this investigation is about 60 feet below the ground surface so that at least 90 feet of the excavation will be in saturated material. Ground water inflows in the alluvium can be effectively controlled by peripheral wells or well points; however, the Tecuya formation appears to be too impervious for these methods to be effective

Cut slope estimates are based on surficial and drill core observations. Near the proposed pumping plant, natural slopes underlain by Tecuya formation are generally quite stable if the angle of the dip of the strata 35 degrees is not exceeded. Locally, where the hillsides have been undercut beyond the dip angle, some minor sliding has been observed. Slopes trending normal to the prevalent dip are generally steeper and more stable. The orientation of the pumping plant is such that its long dimension nearly parallels the strike. The most hazardous potential sliding conditions exist at the southern end of the excavation where the strata are dipping directly into the cut. The recommended slope for the southern wall of the excavation is 2:1 in the Tecuya sediments. The remainder of the excavation slopes should be stable on 1-1/2:1 with berms every 40 feet.

Station A Discharge Lines. The discharge lines from the pumping plant at Station A to the portal of the tunnel will be located on the surface and will be founded on Tecuya sediments, Tejon sandstone, and gneissic diorite. The lower 1,450 feet of the discharge lines will be

founded on deeply weathered Tecuya sandstone and conglomerate. The sediments are overlain by five to seven feet of clayey soil which deepens to about 10 feet at the base of the slope. The weathered zone is approximately 10 feet deep and is characterized by numerous lenses and seams of caliche. In the trench excavated at the base of the slope, the weathered sediments were moderately hard and required some light ripping.

About 800 feet of discharge lines will be on Tejon sandstone. This rock unit is very deeply weathered and decomposed to a depth of at least 30 feet. However, even in a weathered state, this rock appears to be quite stable as evidenced by steep slopes and the absence of slides in the area investigated. The Tejon sandstone is in a fault or sheared contact with the underlying gneissic diorite. The contact lies in a saddle at a point where the discharge lines make a change in direction.

The remaining discharge lines will rest on weathered gneissic diorite. No pronounced zones of weakness or slides were observed in the area, and the foundation appears to be stable.

Tunnels. The tunnels leading from Station A to Station B in the Pastoria Canyon Systems will lie entirely in the gneissic diorite rock unit. Tunnels leading from Pastoria Canyon to the common point in the Beartrap Canyon will penetrate primarily gneissic diorite and, to a lesser extent, rock units of Lebec quartz monzonite and Pelona schist.

Based on geologic reconnaissance mapping, without the aid of any subsurface exploration, three distinct tunneling condition zones were differentiated. The zones and the corresponding rock load factors are shown on Plates 20, 21, and 22 entitled "Relative Tunneling Conditions".

The tunneling zones are related to the physical properties of the rock, which will determine the difficulty of driving the bore and the steel support requirements. The degree of fracturing, chemical alternation, shearing, hardness, and foliation or schistosity were taken into consideration in outlining the tunneling zones. Rock load factors assigned to the tunneling zones represent an average condition and considerable variation should be anticipated under actual tunneling operations. The load factors correspond to criteria developed in Department of Water Resources Bulletin No. 78, Appendix C (1959) entitled "Procedure for Estimating Costs of Tunnel Construction".

Zone 1 - The rock within this zone is overall moderately jointed, unweathered gneissic diorite with some isolated closely fractured zones. The depth of weathering will be about 100 feet and may reach an occasional depth of 150 feet in sheared and closely jointed rock. Weathered rock will only be encountered near the portals and possibly in areas where the cover is 150 feet or less.

Due to shallow cover and the location of the tunnels near the crests of ridges, water inflows are expected to be low. The rock is nonporous and ground water movement will be confined to fractures and shears.

Summary of Tunneling Zone I

Rock Condition	Load Factor	Percent of Zone
Massive, moderately jointed; light support and/or rock bolts.	0 to 0.25B	45%
Hard, schistose. Light support and/or rock bolts required.	0 to 0.5B	45%
Moderately blocky and seamy. Support required. No lateral pressures.	0.35 (B+Ht)	10%

Note: The entire Zone I will be excavated under "dry heading" conditions.

Zone II - Tunneling Zone II includes very closely fractured, sheared and partially decomposed rock units of the gneissic diorite and Lebec quartz monzonite. The rock appears to be within the general zone of influence of the Garlock and the North Garlock fault zones.

Tunneling conditions will range from moderately blocky and seamy to completely crushed, and are expected to vary considerably during tunnel driving. A very marked variance in rock units, intensity of fracturing and shearing, and chemical alteration were observed within this zone during geologic mapping.

Water inflows into the tunnel are expected to be overall low with some moderate inflows confined to isolated closely fractured and sheared intervals.

Summary of Tunneling Zone II

Rock Condition	Load Factor	Percent of Zone
Moderately blocky and seamy. Support required. No lateral pressures.	0.35 (B+Ht)	45%
Very blocky and seamy. Support required. Little or no side pressure.	0.725 (B+Ht)	45%
Completely crushed. Heavy support. Considerable side pressure.	1.1 (B+Ht)	10%

Zone III - This tunneling zone consists of intensely fractured and sheared gneissic diorite near the Pastoria Canyon and the material within the Garlock and the North Garlock fault zones. The rock is chemically altered, mechanically crushed and contains numerous seams of clayey gouge along strong shears. Relatively narrow zones of fractured, unaltered rock were noted within the crushed material. These lenses of better rock appear to be small and are surrounded by sheared, weak material. The depth of weathering and decomposition within the fault zones extends to a depth of at least 200 feet normal to the slope, and is characterized by stained, oxidized rock with open fractures often filled with clay.

Water inflows in this zone are expected to be low owing to shallow cover, and should not constitute a tunneling hazard.

Summary of Tunneling Zone III

Rock Condition	Load Factor	Percent of Zone
Completely crushed. Heavy support required.	1.1 (B+Ht)	50%
Very blocky and seamy.	0.725 (B+Ht)	50%

Pastoria Equal Lift Damsite. This damsite received the most intensive geologic study during this investigation. The site was investigated with seven dozer trenches, nine diamond drill holes, seismic surveys, and detailed geologic mapping. The location of exploration and geologic features within the site area are shown on Plate No. 23. The data obtained from three of the drill holes are not available for inclusion in this report.

The results of the foundation study showed that a wide zone of crushed rock crosses the left abutment ridge, the left abutment, and one of the proposed spillway locations.

Right Abutment. The right abutment has an average slope of about 35 degrees with the lower 75 feet standing on a slope of nearly 60 degrees. Outcrops of moderately weathered and jointed gneissic diorite are nearly continuous along the base of the abutment, becoming spotty and deeply decomposed near the dam crest.

Subsurface exploration on this abutment was confined to one diamond drill hole, DDH-1, located at the base of the slope and drilled to a depth of 81 feet, inclined 30 degrees with the horizontal. Drilling results confirmed the interpretation of foundation conditions based on surficial geologic mapping and can be considered typical of the average quality of the rock on the abutment below the weathered zone. Core recovery in DDH-1 was overall very high, averaging 85 percent. Core losses occurred in soft, decomposed material along prominent fractures and were confined to relatively narrow zones less than two feet in width. The recovered gneissic diorite was fresh, hard, and only moderately fractured. Open fractures were noted to a depth of 60 feet

as evidenced by oxidation and thin clay coatings. No effective water pressure tests were possible to a depth of 60 feet as the tested intervals were taking the maximum output of the pump (about 25 gpm) without any buildup in pressure. The highest losses were interpreted to be along a joint set trending N75W, or nearly normal to the dam axis. These joints have the highest seepage potential as they continue downstream of the embankment area and follow the shortest seepage path around the abutment. Water losses from 60 to 81 feet were relatively low and nearly all fractures appeared to be tight in this interval. Grout takes are expected to be high along the core trench on the right abutment.

Foundation preparation of the right abutment prior to placement of fill for the proposed 122-foot-high dam will consist of the following:

1. Stripping under the impervious section will require removal of all soil, slopewash, talus, and loose rock in addition to 10 feet of deeply weathered, partially decomposed gneissic diorite - an overall average of 15 feet. The lower 75 feet of the abutment slope will require extensive hard rock sloping to provide an even surface for placement of fill. Slush grouting under the impervious section will provide an effective control of near surface fractures in addition to a 100-foot grout curtain to intercept deep seepage.

2. Foundation stripping under the rolled rock fill and compacted alluvium section will consist of removal of all overburden and five feet of weathered rock - an average depth of 10 feet.

Channel. The channel section has a minimum width of 250 feet near the dam axis, widening to 325 feet both up and downstream. The entire channel is filled with stream alluvium and slopewash to a known maximum depth of 34 feet. Bedrock exposures are confined to the base of the abutments.

The channel was explored with two diamond drill holes (DDH-4 and DDH-6) and three seismic lines (see Plate No. 23). Hole DDH-4 was drilled on a 45 degree angle from the base of the left abutment across the channel for a distance of 244.5 feet. Hole DDH-6 was drilled vertically near the center of the stream channel about 50 feet downstream from the dam axis to a depth of 85 feet.

Drill Hole DDH-4 penetrated a fault zone in the interval 36.0 to 76.0 feet below the surface. This zone consists of completely crushed, partially gougy material with very little strength. The crushed rock showed no evidence of surficial weathering and no improvement in the quality of this material should be expected with depth. From 76.0 to 244.5 feet, moderately fractured (average fracture spacing 1.5 per foot), fresh and hard gneissic diorite was cored. Fractures were partially open throughout the cored interval, as indicated by staining and clayey fracture fillings. Thin lenses or zones of completely crushed, gougy rock were encountered throughout the interval. Core recovery was high, averaging 89 percent.

Hole DDH-6 was drilled vertically near the center of the channel with the objective of defining the probable maximum depth

alluvium and the extent of the weathered zone. Bouldery stream alluvium was encountered to a depth of 34 feet and was underlain by virtually fresh, closely fractured gneissic diorite. All major fractures showed alternation, slickenside, and coatings of grey silty gouge. Zones of crushed, gougy material were cored throughout the interval tested - some soft seams appeared to be at least four feet wide and consisted of altered, crushed rock. The average length of recovered rock was 0.4 feet, and the overall recovery was high (75 percent).

Based on subsurface exploration, foundation preparation in the channel section will necessitate removal of 35 to 40 feet of alluvium in addition to 10 feet of loose, partially altered bedrock - a total of 45 feet under the impervious section.

Stripping under the compacted alluvium and rolled rock fill section will consist of 35 to 40 feet of alluvium and five feet of loose rock. The fault zone penetrated by DDH-4 will require overexcavation to at least 20 feet below the cutoff trench elevation and will be backfilled with dental concrete.

Left Abutment. The left abutment is formed by a narrow ridge which has a width of about 700 feet near the dam crest. Outcrops of weathered gneissic diorite were mapped near the base of the slope and a few small exposures were found scattered on the upstream abutment slope. The remainder of the abutment is covered by a deep mantle of soil and slopewash.

The left abutment and the alternate spillway excavation area were explored by six trenches, two diamond drill holes (DDH-2 and DDH-5), and two seismic lines (see Plate No. 23). Subsurface exploration showed the abutment to be covered by an unusually deep cover of slopewash which, in turn, is underlain by deeply weathered and crushed gneissic diorite.

Drill Hole DDH-2 was drilled at an elevation of 2,250 feet, 35 feet above the dam crest to a depth of 151.2 feet, about 25 feet above the channel elevation at the axis of the dam. Overall core recovery was 67 percent. The hole penetrated unconsolidated slopewash to a depth of 36 feet, which consisted of gravelly, silty sand (SM) with partially decomposed boulders of gneissic diorite up to one foot in diameter. Below the overburden to the bottom of the hole, drilling encountered completely crushed, gneissic diorite partially reduced to a silty gouge. The recovered material was typical of the shear zone which was uncovered during trenching exploration, and it appears that Hole DDH-2 lies near the northern boundary of the zone which has an exposed width of 300 feet in the damsite area. No effective water pressure and gravity tests could be performed in the crushed rock as the packer could not be sealed. Water losses during drilling were generally low, and it appears that the gouge which coats nearly all fractures acts as a retardant to seepage.

Hole DDH-5 was located near the proposed axis at elevation of 2,125 feet, about 50 feet above the stream channel. The hole had an inclination of 45 degrees and a bearing of S12W, with a total depth of 107.3 feet. Overall core recovery in DDH-5 was 63 percent,

and water losses during drilling and pressure testing were generally low. Slopewash extended to 16.0 feet and was underlain by partially decomposed, closely fractured gneissic diorite. Fractures were filled with red-brown clay, and water losses during drilling were generally low. The closely fractured, stained, and moderately weathered rock was drilled to a depth of 54 feet. The longest recovered core in this interval was one foot long, and the average core length was 0.3 feet. Intensely fractured, sheared to completely crushed gneissic diorite was encountered from 54 feet to the bottom of the hole (107.3 feet). The average length of core in this interval was 0.1 foot; however, the recovery was exceptionally good, indicating that no wide gouge seams are present. Nearly all fractures showed slickensides and were coated with bluish-grey clayey gouge. The rock fragments within this zone are partially altered but are generally quite hard and difficult to break by hand.

Based on current subsurface exploration, no accurate stripping depth can be predicted for the left abutment. The rock exposed in the trenches and in the diamond drill hole does not appear sufficiently competent for the placement foundation of a 122-foot high dam. Additional exploration is necessary to evaluate the critical foundation conditions on the left abutment.

Spillway. The originally proposed spillway located above the left abutment was found to be entirely in completely crushed, gougy material. The high cut slopes required for the spillway excavation would be highly unstable and would constitute a danger

to a safe operation of the project. The most feasible spillway plan appears to be a glory hole on the right abutment, which would be excavated in competent gneissic diorite.

Pastoria Unequal Lift Damsite. The proposed 120-foot-high dam would be located in a very steep, V-shaped canyon just downstream from the point of confluence of Pastoria Creek with a major unnamed canyon. Geologic mapping and subsurface investigations have revealed a major shear zone which crosses the entire right abutment and continues downstream across the channel of Pastoria Creek. The sheared material consists of completely crushed altered gneissic diorite, which has been partially reduced to clayey gouge. Overall, the right abutment rock appears to be a serious foundation problem for a 120-foot fill structure, and no conclusion as to feasibility of this site can be reached without an extensive exploration program.

Exploration of the site consisted of two trenches, one on each abutment, three diamond drill holes, and two seismic lines. The location of exploratory work and the geologic features are shown on Plate No. 23.

Right Abutment - The right abutment has a steep, even slope, averaging about 35 degrees, and is virtually devoid of trees and brush. Isolated outcrops of closely fractured gneissic diorite are found scattered over the abutment. Later exploration showed that outcrops represent the most competent foundation rock and are completely surrounded by crushed, gougy material. Fresh gneissic diorite exposures near the proposed axis proved out to be talus and slide debris and were underlain by sheared rock. The completely crushed,

gougy rock comprises about two-thirds of the shear zone, with the remainder consisting of intensely to moderately fractured highly altered rock surrounded by weak sheared and decomposed material. The abutment was explored with one long trench extending over the entire abutment and one drill hole, DDH-7. The drill hole was started in moderately fractured rock, as the weaker material continued to slide into the excavation and presented a safety hazard. The hole was drilled to a depth of 98 feet at an angle of 45 degrees with the horizontal, and encountered completely crushed, weak, gougy rock.

The extremely poor nature of the rock exposed in the trench and in the drill core, along with high water losses during drilling, indicate the need for an extensive exploration at this site before the feasibility of a dam 120 feet high can be established.

Channel - The channel section within the dam foundation area is very straight and narrow, averaging 75 feet. The alluvium covers the entire channel and no outcrops were found even at the base of the abutment slopes. Exploration consisted of one diamond drill hole and two seismic lines. The diamond drill hole was located near the axis and was drilled to a depth of 75.5 feet. The first 14 feet consisted of stream alluvium which was underlain by relatively fresh, moderately fractured gneissic diorite. The bedrock is very competent and would provide good foundation for the proposed dam.

Left Abutment - The left abutment has an even steep slope averaging 43 degrees, and is covered by heavy trees and bushes. No outcrops were found within the damsite foundation and the entire slope is mantled by a thick cover of slopewash and slide debris. The left abutment was explored with one long trench about 50 feet above the channel, and by one diamond drill hole 100 feet downstream from the proposed axis. The trenching exploration showed that nearly the entire abutment is covered by deep slopewash and slide debris. No reliable bedrock exposures were found in the trench and all materials encountered appeared to have been disturbed by sliding and creep. Drill Hole DDH-3, 80.5 feet deep on a 45 degree angle, penetrated overburden to a depth of 27 feet. The underlying gneissic diorite bedrock was deeply weathered and closely fractured to a depth of about 55 feet. From 55 feet to 80 feet, the rock was virtually fresh and, although closely fractured, was relatively watertight as indicated in pressure tests. The foundation rock below the overburden appears to be well suited as foundation material for a 120-foot high earthfill dam.

Spillway - A glory hole spillway on the left abutment appears to be the most favorable scheme. The excavation will be in hard, moderately fractured rock, except at the downstream portal where completely crushed material will be encountered.

Station B Pumping Plant, System 1. The proposed pumping plant appears to be situated on an ancient landslide which is underlain by sheared rock. The extent of slide debris shown on Plate No. 23 was

interpreted from surficial geologic mapping and subsurface exploration consisting of two trenches and two diamond drill holes, DDH-8 and DDH-10. The trenches were entirely in slide debris which consist of angular and subangular fragments of gneissic diorite in a matrix of sandy silt. The slide material appears to be quite stable in the trench walls in a dry state. A considerable loss of competency with saturation was observed after prolonged rain, and serious sliding may take place into the reservoir. Excavation of the entire slide is the most effective way of precluding any large scale movement.

Drill Hole DDH-8, located near the toe of the slide, penetrated 59 feet of slide debris which were underlain by completely crushed, gougy material. The hole was drilled to a total depth of 180 feet entirely in weak gougy rock. Similarly crushed rock was encountered in DDH-10. The extent of the weak material in the pumping plant foundation cannot be interpreted without further drilling exploration, and no conclusions as to the feasibility of the plant can be made at this time. The extremely poor quality of the material recovered during drilling makes the interpretation of stable cut slopes and bearing capacity extremely difficult. For purposes of preliminary cost analysis, the following design criteria were defined:

1. Cut slopes in the slide debris will be 1.5:1 and virtually the entire slide will be removed.

2. Cut slopes will stand at 2:1 in fault material and 1-1/2:1 in weathered, closely fractured gneissic diorite.

Station B Pumping Plant, Systems 2 and 3. The proposed pumping plant site is located at the base of a steep, narrow ridge and will require

extensive excavation to provide an adequate foundation. Exploration in the plant area consisted of one trench located near the base of the slope. The material exposed in the trench was almost entirely talus, and only a small section of in-place bedrock was found. The rock at the base of the slope appears to be within the zone of influence of the shear zone located on the opposite canyon slope (see Plate No. 23). Outcrops exposed higher on the ridge indicate hard, moderately fractured rock, and it appears that the bulk of the excavation will be in very hard competent material. Hard rock excavation methods will be used for at least 80 percent of the total excavation and cut slopes will be stable on 1:1, with berms every 50 feet.

Station B Discharge Lines. The discharge lines from the Station B pumping plant of the Two Equal Lift System lie entirely in an area of very deep slopewash and landslide debris. The average estimated depth of overburden is 20 feet, reaching a maximum of over 50 feet near the base of the slope. The nature of the underlying bedrock is not known, as there are no outcrops and no subsurface exploration has been done at the time of writing. The zone of intensely fractured to completely crushed rock which crosses the pumping plant area appears to underlie at least a portion of the discharge lines foundation with the remainder to be founded on deeply weathered gneissic diorite. The general instability of the foundation rock is attested by the old landsliding and the total absence of outcrops. A comprehensive subsurface exploration program of the area is needed for a proper evaluation of the foundation conditions.

The discharge lines of the Station B pumping plant of the Pastoria Two Lift and Ridge-Pastoria Two Lift will be founded almost entirely on hard,

moderately weathered and fractured gneissic diorite, and no unusual construction difficulties are anticipated. About 50 percent of the required excavation will be by hard rock methods.

Ridge Alignments

A geologic study of the Ridge alignment has been in progress intermittently since 1960. This summary report presents the engineering geology and exploration of the proposed engineering features along the ridge alignment. Since geological investigation is in progress, conclusions are tentative and subject to revision.

The topography, location of engineering work, and distribution of geologic units is shown on plates 24, 25, 26, and 27.

Forebay. The forebay excavation will be mostly in alluvium which is predominantly silty sand. Recommended cut slopes in the forebay excavation are 2:1 with berms.

At the location of the forebay dike, 0 to 60 feet of alluvial materials overlie fractured basalt. Based on water pressure tests and examination of the core from drill holes, extensive grouting will be required in the highly fractured basalt to prevent leakage.

Station A Pumping Plant. The pumping plant will be founded entirely upon the Tejon formation which dips 30 to 35 degrees to the northwest and consists of firm sandstone with minor interbeds of siltstone. The alluvium overlying the Tejon formation ranges from 5 to 65 feet in thickness. The depth to static water averages 20 feet below ground surface; no unusual dewatering problems are anticipated. The sandstones will require ripping

with possibly some light blasting. Cut slopes should be stable at 1-1/2:1 with berms except at the southern end of the excavation where the beds dip into the excavation and will require 2:1 slopes for stability. Limited rock testing indicates the sandstone has adequate strength for the proposed structure. Based on geophysical surveys and trenches, a fault crosses the foundation area, and two other faults are suspected. It may be necessary to shift the position of the pumping plant slightly to avoid placing it on weak materials associated with the faults.

Discharge Lines. The discharge lines were investigated for both surface and underground alignments for the single-lift and surface for the two-lift systems. All of these features are located within the gneissic diorite body. In general, the gneissic diorite is a hard and strong rock with an average fracture spacing of 4 feet. Foliation and banding are usually well developed with a predominant trend of N45W or roughly parallel to the alignment of the discharge lines. Dips of foliation are usually steep to the east, although local variations in both strike and dip are common. Although folding is difficult to distinguish, several localities indicate that tight isoclinal folding is an important aspect of rock structure.

As displayed in trenches, several shear zones traverse the area in a northeast direction. These zones, from 2 to 10 feet wide, are composed of sheared, decomposed to highly fractured rock affected by mineralization and chemical alteration. A few thin clay gouge seams are also present.

Decomposed rock resulting from surface weathering has a maximum known depth of 95 feet but averages 10 feet along the discharge lines. Any

underground features, such as discharge lines, will be below the water table; ground water should not affect any of the proposed surface works.

Rock test results obtained so far indicate that the gneissic diorite is competent and suitable as a foundation material for surface and underground discharge lines.

Off-line Damsite. The proposed 167-foot-high dam will lie in a V-shaped narrow canyon with an extremely steep gradient. Foundation rock consists of moderately to deeply weathered gneissic diorite which is cut by numerous two to five feet wide pegmatite veins. Outcrops are very spotty, and the entire damsite area is mantled by soil with widespread evidence of shallow creep.

The site was explored with two trenches, one on each abutment, and three drill holes. Additional two drill holes and an investigation of the potential borrow areas is in progress. Overall the site appears to be well suited for a combination earth and rockfill dam, and no serious construction problems are anticipated. Based on preliminary diamond drilling information, the site may be adequate for construction of a concrete structure, as hard competent rock was found below the surficially weathered material. Additional drilling information is needed to further substantiate the feasibility of a concrete dam at this location.

Right Abutment. The right abutment has an even slope, averaging 25 degrees. Outcrops are confined to the stream channel and are deeply weathered. Above the channel there are very few outcrops consisting primarily of pegmatite dikes. The abutment was explored by one trench about 60 feet above the channel, and

one drill hole, DH-1, 181 feet deep. The trench revealed deeply weathered, but only moderately fractured, gneissic diorite and no major zones of weakness were found. Hole DH-1 was drilled from the trench into the abutment on a 60 degree angle to a total depth of 131 feet. The hole penetrated moderately to deeply weathered gneissic diorite to a depth of 45 feet. The intensity of weathering within this zone was highly irregular and generally confined to prominent fractures or sets of joints. Overall there is a noticeable improvement in the rock condition at 24 feet. The fracture spacing in the interval 0 to 45 averaged 0.5 feet, and virtually all fractures showed oxidation and rusty staining. Water losses during pressure testing 0 to 45 feet ranged from 15.8 to 4.8 gallons per minute at 50 psi for a 10-foot tested interval.

A very abrupt change in the rock condition takes place at 45 feet. The rock below 45 feet is fresh and hard, and the rust staining is confined to isolated, prominent fractures. The improvement in the rock condition is readily reflected in the water test results. Water "takes" below 45 feet drop to one to four gpm at 50 psi for a 10-foot tested interval. Fracture spacing from 45 to 131 feet averaged about 0.8 feet with the most intense fracturing in pegmatite veins.

Foundation preparation for a 167-foot-high fill dam will consist of the following:

1. Impervious core - strip 25 feet of deeply weathered, deeply fractured rock.

2. Rockfill and gravel section - remove 15 feet of deeply weathered rock.

Channel. The channel section consists of a V-notch and is covered by shallow slopewash and soil. It was too narrow to be discussed separately, and is covered under the description of the abutments.

Left Abutment. The left abutment has a very steep slope averaging 33 degrees and it is virtually devoid of any outcrops. Exploration consisted of one trench and two diamond drill holes. The drilling results are incomplete at the time of writing.

Trenching revealed a deep soil mantle five to ten feet deep underlain by decomposed, friable, gneissic diorite. No major shearing or crushing was observed, and the foundation rock should improve below a depth of 25 to 30 feet. The following preliminary stripping estimates are based primarily on near surface information and may undergo some revision upon completion of the drilling exploration:

1. Impervious section - strip 30 feet of soil and decomposed rock.

2. Rockfill and gravel sections - strip 20 feet of overburden and decomposed rock.

Station B Pumping Plant. Exploration of the proposed pumping plant consisted of 2 trenches and 1 access road. Further exploration will include 2 diamond drill holes, a geophysical study, and associated rock testing.

Based on current information, the pumping plant will be located on hard, strong, fractured gneissic diorite, and no unusual construction problems are expected. The trenching exploration revealed at least 4 minor faults in the plant area, which ranged in width from 2 to 3 feet. The depth of deeply decomposed rock which could be removed by common excavation methods was estimated to be about 20 feet. Numerous partially decomposed hard residual ribs are found throughout the plant area and will require blasting. The rock below 20 feet will contain a great percentage of hard, weathered diorite and will require blasting.

The cut will be almost entirely in hard, weathered gneissic diorite and will be stable on a 1:1 slope with berms.

Tunnel No. 1. This tunnel will traverse competent gneissic diorite and will be entirely within tunneling Zone I as outlined in the discussion of tunnels in the Pastoria alignments. Tunneling Zone I is estimated to contain 45% massive, moderately jointed rock, 45% hard, foliated rock, and 10% moderately blocky and seamy rock. Maximum cover over Tunnel 1 is 600 feet. The tunnel invert is below the water table, but will be excavated under a "dry heading" condition, which is defined as water inflows less than 100 gallons per minute at the tunnel heading. In general, foliation trends parallel to or at a slight angle to the tunnel alignment. No major faults were mapped in this area.

Tunnel No. 2. Tunnel No. 2, to be excavated entirely within gneissic diorite, will generally encounter tunneling Zone I as outlined above except for the area immediately adjacent to the outlet portal which will traverse tunneling Zone II. Tunneling Zone II, also, explained in

the discussion of tunnels in the Pastoria alignments, consists of 45% moderately blocky and seamy rock, 45% very blocky and seamy rock, and 10% completely curshed rock. Maximum cover above Tunnel 2 is 560 feet. All of the tunnel is below the water table but "cry heading" conditions are anticipated. Foliation is somewhat erratic, but will generally intersect the tunnel at an angle of about 30 degrees. The south portal of Tunnel No. 2 lies just within the borders of the west branch of the North Garlock fault. No other faults are known to intersect Tunnel No. 2.

<u>Siphon No. 2</u>. Siphon No. 2, which has a total length of about 2,500 feet, will be entirely within the North Garlock fault zone. In this area the east and west branch faults meet to form a wide zone characterized by highly fractured, locally altered gneissic diorite containing 5 to 20-foot-wide seams of fault breccia and clay gouge at irregular intervals. Based on 4 drill holes and 4 trenches, the fault zone is composed of about 50 percent strongly fractured, weathered to altered, moderately hard gneissic diorite containing about 50 percent seams and zones of sheared, weak and crushed fault gouge and breccia. Some of the faulted rock has been re-cemented to become somewhat more competent. Surface weathering has decomposed the rock to a depth of at least 25 feet. Adequate rock for the foundations of anchor blocks and portal structures may require excavation to depths of at least 35 feet. Estimated side slopes of 1:1 should be stable in the cut required for the reinforced concrete pipe. The excavation should be dry except where it intersects the bottom of the canyon where the water level is about 10 feet below ground surface. Common excavation with some ripping will be required for the shallow trench.

Tunnel No. 3. Tunnel No. 3, about 5,700 feet long, will traverse 1,100 feet of gneissic diorite and 4,600 feet of the Pelona formation which consists of quartz mica schist with lessor amounts of sericite schist, chlorite schist, graphite schist, talc schist, mylonite, and quartzite. About one-half of Tunnel No. 3 will encounter Zone II tunneling conditions, and the remainder of the tunnel will be excavated in Tunneling Zone III. As explained in the discussion of tunnels in the Pastoria alignments, Tunneling Zone III consists of 50 percent completely crushed rock and 50 percent very blocky and seamy rock; this weak material is contained within the Garlock and North Garlock fault zones as well as in other areas of faulted rock.

The maximum cover above Tunnel 3 is 600 feet. Most of the tunnel can be advanced by dry heading methods, although short intervals of moderate water inflows may be expected on the hanging wall side of faulted rock under high cover. Foliation is variable but, in general, is nearly normal to the tunnel alignment.

Exploration of Engineering Features. Geological mapping at a scale of 1" = 400' has been completed for the entire alignment and, in addition, the following features have been investigated with varying degrees of intensity:

1. Station A Pumping Plant

    (a) 22 rotary drill holes; 3,000 feet total

    (b) 6 trenches

    (c) 2 dragline pits

    (d) Seismic refraction surveys; 10 lines

    (e) Magnetometer survey

    (f) Soil and rock testing

2. Discharge Lines - to include both surface and underground alignments.

   (a) 7 rotary drill holes; 6,400 feet total

   (b) 4 trenches

   (c) Seismic refraction survey; 4 lines

   (d) Rock testing

3. Station B Pumping Plant

   (a) 2 rotary drill holes (proposed)

   (b) 2 trenches

   (c) Seismic refraction survey (proposed)

   (d) Rock testing (proposed)

4. Off-Line Damsite

   (a) 4 rotary drill holes (in progress)

   (b) 5 trenches (in progress)

   (c) Seismic refraction survey (proposed)

   (d) Rock testing (proposed)

   (e) Borrow materials investigation (proposed)

5. Tunnel No. 1

   (a) 6 rotary drill holes; 1,850 feet total

   (b) 2 trenches (proposed)

6. Siphon No. 1

   (a) 2 trenches (proposed)

   (b) Seismic refraction survey (proposed)

7. Tunnel No. 2

   (a) 2 rotary drill holes; 310 feet total

   (b) 1 trench

8. Siphon No. 2

   (a) 2 rotary drill holes; 211 feet total

   (b) 2 trenches

   (c) Seismic refraction survey

9. Tunnel No. 3

   (a) 15 rotary drill holes; 4,900 feet total

   (b) 1 trench

   (c) 1 test adit; 350 feet total

   (d) Rock testing (proposed)

   (e) Seismic refraction survey (proposed)

Engineering Analysis

This section presents summarized engineering analyses of the specific features included in the six lift systems described earlier in this report.

Forebays

The criteria for determining forebay capacity are that water would be made available to supplement impaired inflow rates by a total amount equal to one-half hour's flow at design discharge of 4,093 cfs, and that storage capacity would be reserved to store excessive inflows in the same amount. Each of these criteria requires an impounding capacity of about 170 acre-feet, or 340 acre-feet total.

The forebay serving the first plant in the Tehachapi pumping lift complex was assumed to be a separated or by-pass type, in which the water surface is maintained at a lower elevation than the canal normal water surface. For this separate type forebay, a canal-to-forebay overflow weir is provided of sufficient length to discharge excess inflow at a rate equal to the canal design discharge with canal surcharge not exceeding the permissible freeboard. The forebay water surface would be returned to its normal operating elevation, after storing excess inflows, either by drawing down the canal water surface to the normal operating forebay level or by pumping the forebay until the desired forebay operating water surface is reached.

When deficient inflow occurs, it is necessary to draw the intake canal surface below the level of the forebay in order to use forebay water for flow augmentation. After a period of deficient inflow, the forebay control gates would be operated to return water to the forebay as (or after) the intake canal surface is restored to normal elevation.

An emergency spillway would be provided to discharge the normal canal flow, at a surcharge not exceeding the freeboard of the canal or forebay, in the event that canal inflow might exceed pump discharge, with the forebay at maximum water surface level.

Although a forebay is included in this study, investigations are being made on the possibility of eliminating the forebay. Flow augmentatio would be provided from drawdown of the water surface in the canal and exces flows would be either wasted at a blowoff or discharged into a spill basin.

Pumping Plants

Civil. The pumping plant structures are enclosed surface structures which house 14 and 8 units for the single and two-lift systems, respectively. The space requirements of the electrical and mechanical equipment and, therefore, the size and arrangement of the structures are based on equipment sizes from manufacturers' data. The structures are designed with an adequate volume of concrete to satisfy the basic stability requirements.

Mechanical. The mechanical features of the six alternative lift systems have been selected on the basis of the criteria stated earlier in this report and the following analyses:

Pumps. The pumps selected for the systems have characteristics closely approximating the design for which model test programs are presently in progress. The characteristics of the selected pumps are given in Table III-2. The efficiencies are consistent with those obtained from the preliminary model tests on the different pump designs.

While the vertical configuration is the only practical one for the four-stage single suction pump installation, the horizontal configuration has certain merits in the two-stage double-flow pump installation. In previous studies, plant layouts were made for both configurations of the two-stage double-flow pumps; their relative costs were estimated and it was found that the vertical design was more economical. Because the pumps selected in the present study are very similar to those of previous studies, the vertical configuration has been selected again.

It will be noted that two values for submergence are given in Table III-2 for each pumping station. One is that required for safe operation under normal ultimate flow conditions; the other is the maximum required for the same safe operation under the assumed operating conditions existing during the water-buildup period.

Discharge Valves. The spherical valve with double sealing was selected after a comparison was made with the same type having only a single seal and with a rotary cone type of valve. It has the advantage of enabling internal inspection, maintenance and replacement of the operating seal without unwatering the discharge line or necessitating the installation of an adjacent guard valve. It is designed with "fail-safe" operating characteristics and has a negligible head loss. The "high-head" butterfly valve was not given detailed consideration due to the high value of its head loss.

Auxiliaries. The cranes, and the raw and cooling water, lubricating oil, drainage, transformer oil, compressed air, fire protection, plumbing, heating, ventilation and air conditioning systems were selected on the basis of general good practice for the specific conditions of use.

Hydraulic Transients. Preliminary studies of hydraulic transients for each of the alternative lift systems showed that the profiles and designs of all discharge lines were satisfactory. Under the conditions of loss of power at the different lift stations, the negative pressure surge lines were located safely above the discharge

lines at all points, and the excess transient pressure surges added to the normal internal operating pressures were safely under the design pressures.

Electrical. The electrical features for the single-lift and two-lift systems have been selected on the basis of the following analyses:

230 KV Switchyard. The voltage and number of transmission lines assumed to terminate at the switchyard are based on a circuit loading of approximately 200 MW, which is derived in part from data in Table 18 of the Federal Power Commission Technical Memorandum No. 1. The switchyard main and transfer bus arrangement were selected on the basis of economy, simplicity, and common usage. The use of overhead power connections and buried duct for control cables from the switchyard to the plant is based on economy and technical feasibility. The provision of a single control room for plant and switchyard located at the plant is based on common practice.

13.8 KV System. The assumption of full voltage starting of the main pump motors as induction motors is based on preliminary information obtained from motor manufacturers. A final determination of starting method will be made during the final design phase of the Tehachapi lift system.

The selection of self-cooled (OA rated) main transformers with fans for operation at higher ambient temperatures (FA rating) is based on the most conservative practice. The use of a single, three-phase transformer is favored by the increased reliability of modern

transformers whereby the possibility of failure is remote through proper protection. With this reliability, it is considered feasible to connect two or three motors to each transformer, thus gaining a considerable overall economic advantage. The use of segregated phase bus for the motor-transformer connections is consistent with the continuous and monetary current ratings encountered. The use of metalclad switchgear is determined by the interrupting requirements as derived from fault calculations. The degree of motor protection is based on recommended conservative practice.

480-Volt System. The loadcenters supplying auxiliary power are of the conventional type and utilize a "throwover" scheme to assure continuity of service to essential auxiliaries.

Discharge Lines

Surface Pipes. After consideration was given to a greater number of lines, two barrels were selected as the optimum number. The economical diameter was determined by calculating that size which yields the least total present worth cost of construction, including capitalized maintenance and replacement, and the present worth cost of energy losses due to frictio The use of a range of pipe diameters was considered but the difference in cost between constant and varying diameters installations was judged to be of secondary importance, and since all discharge lines would be similarly effected, the comparison between systems would be valid. When the final system is selected, a more exacting analysis on optimum diameter will be m

The type of construction used for estimating costs was welded steel pipe, mechanically coupled and supported on concrete saddles spaced at 40-foot intervals. The plate thickness was determined by using the hoop tension formula $t = \frac{2.6HD}{f_s}$ where t is the plate thickness in inches, H is the head in feet, D is the diameter in feet, and f_s is the allowable working stress of the steel. The minimum plate thickness is equal to $\frac{D+20}{400}$ where D is diameter in feet. The heads were based on the static head plus 15 percent for normal surge. Abnormal upsurges caused by power failures were not used in determining plate thicknesses since the upsurge will not exceed 50 percent of static head whereas Department criteria allows an increase of 50 percent of the allowable stresses under such conditions. The allowable stresses used were consistent with Department recommendations except in the case of A-517 steel where an allowable stress of 38,300 psi (1/3 of ultimate instead of 1/2 of yield) was used. The types of steel used are A-285C, A-441 and A-517 as governed by economy.

Discharge Tunnels. The number of discharge tunnels was selected as two. This was considered as a minimum in order to avoid complete shut-down of water deliveries for reasons of maintenance or emergency repairs to either tunnel. The inside diameter of 12.0 feet was determined to be optimum by calculating the least total present worth of construction costs, capitalized maintenance and replacement costs, and the present worth cost of hydraulic losses.

The profile of the tunnels is stepped to minimize the external hydrostatic pressure on the steel liners. A 12-foot adit is provided to the second step for access during construction and for maintenance after

operation begins. This adit may be used as a second heading during construction and is large enough to transport the steel liners into the discharge tunnels during construction.

The tunnel discharge lines were designed to withstand the full internal hydrostatic pressure plus 30 percent of static head for upsurge and for external hydrostatic pressure equal to a column of water equal to the height of cover over the tunnel. The design of the steel liners for internal pressures was based on the theory presented by Mr. E. W. Vaughn in the Journal of the Power Division of the American Society of Civil Engineers, No. PO 2 of April 1956, entitled "Steel Linings for Pressure Shafts in Solid Rock".

Mr. Vaughn's theory of rock deformation was based on the elastic theory with certain reservations for inelastic behavior. The theory was developed on the assumption that the rock can take all of the tensile stresses resulting from internal pressure. In essence, the design load is proportioned among the steel liner, concrete liner and the rock according to the assumption that the steel, rock and concrete would deform alike when loaded.

The reliability of the results is limited by the accuracy in correlating laboratory data of the elastic properties of rock to in-situ conditions. Based on the geologic exploration program in progress, testing of core samples and available literature, the following data were used in applying Vaughn's theory:

Ratio of plastic to elastic deformation $K = 0.1$

Gap between steel liner and concrete $= .0003R_s$ where

R_s is the radius of the steel liner

Modulus of elasticity of rock $E_R = 3 \times 10^6$ psi

(Approximately 50 percent of minimum static modulus of elasticity as determined by laboratory tests)

Modulus of elasticity of concrete $E_c = 3 \times 10^6$ psi

In the application of Vaughn's theory, the rock was assumed capable of withstanding tensile stresses. Natural prestressing of the rock is relied upon to compensate for the tensile stresses induced by the water pressure in the tunnel. In view of our assumption that rock can withstand induced tensile stresses, adequate rock cover was assumed to be 40 percent of the total internal head carried by the rock. This amount of cover overcompensates for the tensile stresses induced by internal pressure and the rock is then all in compression; our assumption is justified. Rock bolts are used to minimize stress relieving of the rock as excavation progresses. If rock support is less than adequate, the steel liner thickness was increased proportionately between no rock support and full rock support.

The steel liners were also designed to resist external pressures caused by grouting during construction and ground water acting upon the empty tunnel. The design of the steel liner to resist all of the external pressure was also based on Vaughn's paper. However, where the use of circumferential ring stiffeners resulted in a more economical design, the steel liners were designed using Timoshenko's theory for a freestanding pipe with rigid stiffener rings. The weight of the rings was assumed 20 percent of the weight of the liner where the rings were effective.

Two types of steel are used for the lining, A-285C and A-441, as governed by economy. The allowable stresses used, which are 70 percent of yield stress, are:

A-285C	21,000 psi
A-441	32,200 psi

Tunnels

For all tunnels, except the tunnel discharge lines, one tunnel with a diameter of 23.5 feet is used. The finished cross section is circular within a horseshoe excavation. The tunnels are concrete-lined with continuous support with steel ribs and invert struts. Fifty feet of cover was maintained along the entire alignment of the tunnels.

Siphons

For short reaches of siphon (up to 1,000 feet in length), a single barrel of cast-in-place concrete pipe, with the same diameter as the contiguous tunnels, is used. For siphons of greater length, multibarrel prestressed concrete pipe is used.

Dams

The reservoirs in the multilift systems serve five primary functions: conveyance of aqueduct flows, damping of surges, accommodating mismatching of pumping units between the first and second pumping plants, providing temporarily for storage of inflows from Station A in the event of accidental stoppage of the Station B, and temporarily for the draft of the Station B if Station A suffers an accidental outage.

Sizing of reservoirs was based on supplementing inflow deficiencies equal to 15 minutes flow at design discharge, and on providing available space that would be required to store excessive inflows of the same amount. These criteria would require $\pm$ 85 acre-feet capacity or 170 acre-feet total active capacity.

Flood Hydrology. All reports pertaining to the hydrology of the area were reviewed and compared, and a conclusion reached that the unit hydrograph for Pastoria Creek published in the Department's office report, "Hydrologic Studies for California Aqueduct Cross-Drainage Design", was of sufficient detail that the probable maximum discharge could be established.

Because of the consideration for maximum safety of the Pastoria Canyon Dams, it was decided that the estimated probable maximum storm flow would be added directly to aqueduct inflow, and this new peak inflow would be used in designing emergency spillways. The probability of the maximum flood flows and full aqueduct discharge rejection at the reservoirs occurring at the same time is remote, but still possible. The spillway design discharge for the Ridge Off-line Reservoir is full aqueduct capacity. Natural flood inflows are negligible since rainfall intensities are low and the tributary drainage area is only 0.6 square miles.

Debris Inflow. A reconnaissance of the drainage area revealed that there had not been a great amount of debris production in recent years.

Based upon all available data on precipitation and runoff, records of all fires in the drainage area during the last 25 years, and reports on debris production and soil erosion, it is estimated that debris dams and/or check structures are not required at this time but should be constructed as needed if the present conditions of the watershed change. There is a great potential for debris production in the Pastoria Creek watershed if a large portion of the ground cover is burned.

Embankment Design. The dams were designed as zoned earth-and-rockfill embankments. Construction costs were estimated on structural embankments based on conservative designs since there are no available data on soil test results of the foundations or construction materials. The exterior slopes were assumed to be 3:1 upstream and 2.5:1 downstream. All dams are 40 feet wide at the top and have a curved axis.

Construction materials were assumed acceptable for dam construction. These materials would be obtained from (1) foundation excavation, (2) pumping plant excavation, (3) quarry and borrow sites outside the reservoir.

Spillways. The cost estimates are based on uncontrolled glory hole spillway. The glory hole was designed to carry the estimated probable maximum storm and aqueduct flow at a maximum 10-foot surcharge. The discharge tunnel would convey these flood releases past the dam embankment and discharge the flows into natural drainage channels.

CHAPTER IV. COST ESTIMATES AND ECONOMIC COMPARISON

The estimated costs for the six Tehachapi alternative lift systems are summarized in Table IV-1. Detailed estimates of capital costs are given in Table IV-2, and annual costs in Table IV-3. Only the applicable electrical and mechanical equipment was staged, according to staging schedule as shown on page III-1. Consideration was given to staging surface discharge lines; however, since the second line would have to be installed and ready for operation in 1972, costs were distributed assuming both lines installed for initial delivery.

Capital Costs

Costs for structures and conveyance conduits were estimated by determining quantities of excavation, concrete, pipe, etc., and applying appropriate unit costs. Mechanical and electrical equipment costs were estimated by using catalog prices or manufacturers' quotations and adding delivery and installation costs.

Allowances for engineering costs and for contingencies were estimated as follows:

Contingencies:

Dams	- .25 x construction cost
Other	- .15 x construction cost

Field cost	- construction + contingencies
Preliminary design	- .03 x field cost
Final design	- .05 x field cost

Construction supervision:

Forebays, roads, and canals	- .15 x field cost
Other	- .07 x field cost

Total capital cost was determined as the sum of field cost, design costs, and construction supervision cost.

Annual Costs

For pumping plants, estimates were made of operating manpower requirements with an additional allowance for administrative costs and materials. For other features, operation, maintenance, and replacement are based on percentages of capital costs. Electrical power and energy costs are based on Power Office Schedule No. 3A, as shown in Table III-1.

Economic Factors

All present worth values are referenced to year 1965 and include all estimated costs through year 2040, discounted at an interest rate of four percent per annum.

TABLE IV-1

COST SUMMARY

In thousands of dollars

Systems	Cost	Present worth cost	Excess present worth over System 6	Percent excess present worth over System 6
Pastoria Two-Equal Lift				
System 1				
Capital	156,711	138,517	2,683	1.98
Annual O.M. and R.	2,008	38,680	3,321	9.39
Annual power and energy	19,250	284,627	- 333	- .12
TOTAL	177,969	461,824	5,671	1.24
Pastoria Two Lift				
System 2				
Capital	164,940	146,075	10,241	7.54
Annual O.M. and R.	2,027	39,065	3,706	10.48
Annual power and energy	19,341	285,966	1,006	.35
TOTAL	186,308	471,106	14,953	3.28
Ridge-Pastoria Two Lift				
System 3				
Capital	175,362	155,924	20,090	14.79
Annual O.M. and R.	2,056	39,751	4,392	12.42
Annual power and energy	19,266	284,861	- 99	- .03
TOTAL	196,684	480,536	24,383	5.35
Ridge Two-Equal Lift				
System 4				
Capital	162,783	144,869	9,035	6.65
Annual O.M. and R.	2,060	39,861	4,502	12.73
Annual power and energy	19,223	284,241	- 719	- .25
TOTAL	184,066	468,971	12,818	2.81
Ridge Single Lift With Underground Discharge Lines				
System 5				
Capital	155,692	137,820	1,986	1.46
Annual O.M. and R.	1,824	35,234	- 125	- .35
Annual power and energy	19,499	286,676	1,716	.60
TOTAL	177,015	459,730	3,577	.78

COST SUMMARY
(continued)

In thousands of dollars

Systems	Cost	Present worth cost	Excess present worth over System 6	Percent excess present worth over System 6
Ridge Single Lift With Surface Discharge Lines System 6				
Capital	153,645	135,834	--	--
Annual O.M. and R.	1,830	35,359	--	--
Annual power and energy	19,418	284,960	--	--
TOTAL	174,893	456,153	--	--

TABLE IV-2

CAPITAL COST

In thousands of dollars

Description	System 1[a] Cost	System 1[a] Present worth	System 2[b] Cost	System 2[b] Present worth	System 3[c] Cost	System 3[c] Present worth	System 4[d] Cost	System 4[d] Present worth	System 5[e] Cost	System 5[e] Present worth	System 6[f] Cost	System 6[f] Present worth
Civil												
Lift No. 1												
Approach canal	1,026	970	1,026	970	5,506	5,205	5,506	5,205	5,506	5,205	5,506	5,205
Forebay	5,009	4,736	5,009	4,736	6,505	6,150	6,505	6,150	6,505	6,150	6,505	6,150
Plant structure	11,763	10,470	11,819	10,520	11,900	10,592	11,527	10,260	19,416	17,282	19,408	17,275
Site development	2,737	2,599	2,737	2,599	5,553	5,273	5,553	5,273	10,426	9,899	7,496	7,117
Discharge lines	9,342	8,315	10,989	9,781	9,568	8,516	8,280	7,370	24,670	21,959	25,462	22,664
Upper terminus structure	557	496	557	496	557	496	557	496	634	564	894	796
Tunnels	17,320	15,417	20,423	18,179	22,163	19,727	--	--	37,199	33,111	37,199	33,111
Siphons	--	--	--	--	--	--	--	--	3,458	3,078	3,458	3,078
Lift No. 2												
Dam	9,605	8,423	10,028	8,793	10,028	8,793	4,238	3,716				
Plant structure	10,352	9,214	10,182	9,063	10,179	9,060	10,115	9,003				
Site development	1,587	1,507	6,108	5,800	6,108	5,800	7,134	6,774				
Discharge lines	5,247	4,670	5,237	4,661	5,237	4,661	8,013	7,132				
Upper terminus structure	557	496	557	496	557	496	557	496				
Tunnels	25,266	22,489	25,006	22,258	25,006	22,258	37,199	33,111				
Siphons	4,101	3,651	1,689	1,504	1,689	1,503	3,458	3,078				
Access Roads	5,595	5,290	5,822	5,504	7,152	6,762	6,900	6,523	4,175	3,947	4,175	3,947
Civil Subtotal	110,064	98,743	117,189	105,360	127,708	115,292	115,542	104,587	111,989	101,195	110,103	99,343
Mechanical												
Pumps	14,732	12,502	15,172	12,875	15,130	12,839	14,736	12,505	15,745	13,142	15,673	13,082
Valves	5,926	5,028	5,843	4,958	5,843	4,958	6,562	5,569	4,166	3,478	4,166	3,478
Cranes	563	523	598	556	598	556	572	532	311	289	311	289
Auxiliaries	1,805	1,580	1,836	1,608	1,832	1,604	1,806	1,582	1,445	1,263	1,440	1,259
Mechanical Subtotal	23,026	19,633	23,449	19,997	23,403	19,957	23,676	20,188	21,667	18,172	21,590	18,108
Electrical												
Motors	12,865	10,917	13,215	11,214	13,172	11,178	12,816	10,876	12,415	10,363	12,352	10,310
Transformers	2,843	2,453	2,843	2,453	2,834	2,445	2,837	2,447	2,689	2,250	2,668	2,233
Auxiliaries	3,071	2,606	3,419	2,901	3,419	2,901	3,071	2,606	3,153	2,631	3,153	2,631
Switchyards	4,842	4,165	4,825	4,150	4,826	4,151	4,842	4,165	3,779	3,209	3,779	3,209
Electrical Subtotal	23,621	20,141	24,302	20,718	24,251	20,675	23,565	20,094	22,036	18,453	21,952	18,383
TOTAL CAPITAL COST	156,711	138,517	164,940	146,075	175,362	155,924	162,703	144,069	155,692	137,820	153,645	135,834

a. Pastoria Two-Equal Lift
b. Pastoria Two Lift
c. Ridge-Pastoria Two Lift
d. Ridge Two Lift
e. Ridge Single Lift With Underground Discharge Lines
f. Ridge Single Lift With Surface Discharge Lines

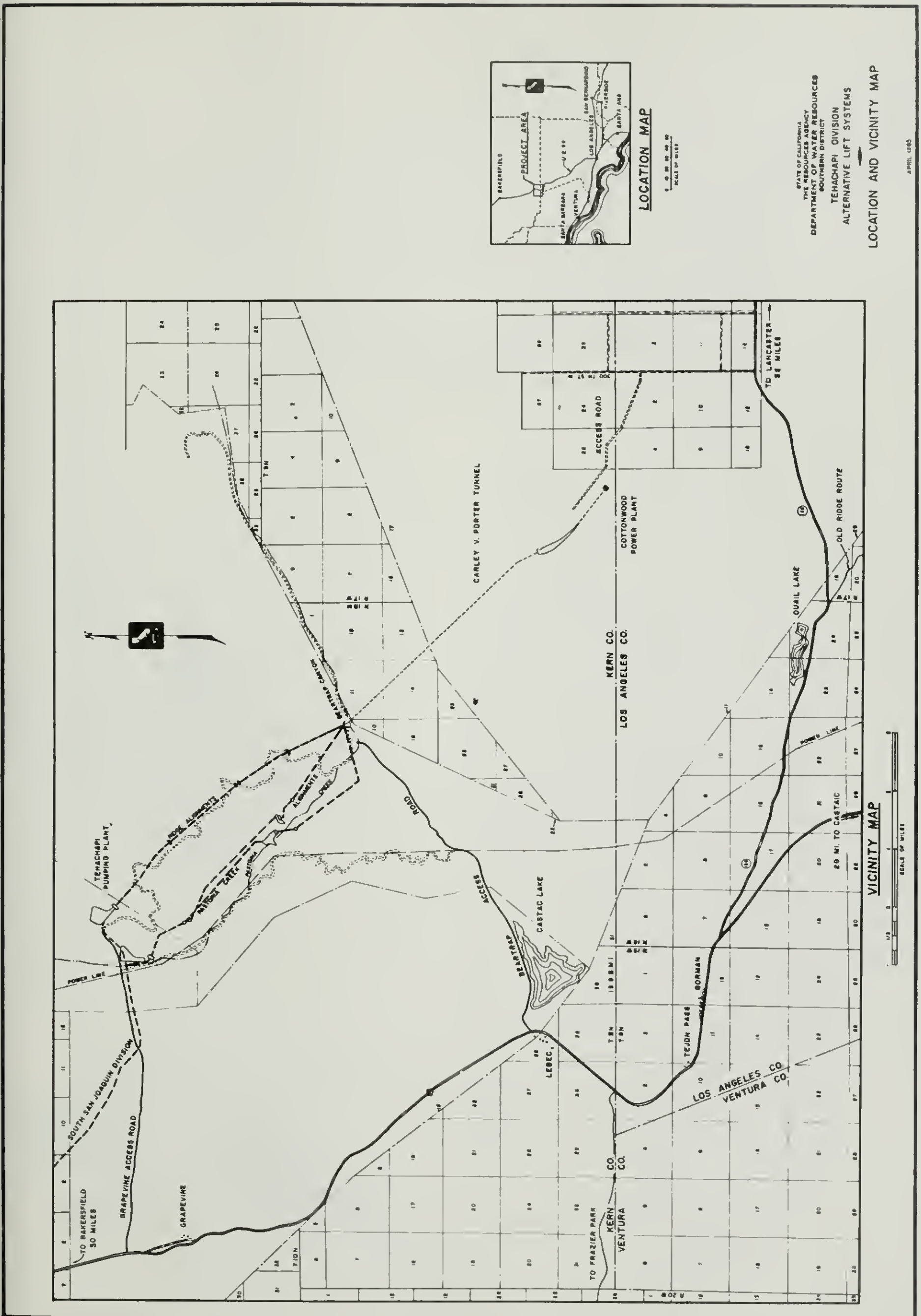
TABLE IV-3

ANNUAL COSTS

In thousands of dollars

Description	System 1[a]		System 2[b]		System 3[c]		System 4[d]		System 5[e]		System 6[f]	
	Ultimate annual	Present worth	Ultimate annual	Present worth	Ultimate annual	Present worth	Ultimate annual	Present worth	Ultimate annual	Present worth	Ultimate annual	Present worth
Operation, maintenance, and replacement												
Lift No. 1												
Approach canal	6.6	150	6.6	150	35.3	802	35.3	802	35.3	802	35.3	802
Forebay	1.0	23	1.0	23	1.0	23	1.0	23	1.0	23	1.0	23
Plant	878.1	16,726	882.9	16,823	882.1	16,807	878.2	16,747	1,481.2	28,160	1,478.1	28,097
Site development	--	--	--	--	--	--	--	--	--	--	--	--
Discharge lines	84.1	1,686	98.9	1,983	86.1	1,726	74.5	1,494	222.0	4,451	229.1	4,593
Upper terminus structure	5.0	100	5.0	100	5.0	100	5.0	100	5.7	114	8.0	160
Tunnels	10.7	215	12.7	255	13.7	275	--	--	23.1	463	23.1	463
Siphons	--	--	--	--	--		--	--	13.5	271	13.5	271
Lift No. 2												
Dam	5.0	100	5.0	100	5.0	100	5.0	100	--		--	
Plant	878.0	16,726	882.9	16,822	882.0	16,807	878.2	16,747	--		--	
Site development	--		--		--		--		--		--	
Discharge lines	47.2	946	47.1	944	47.1	944	72.1	1,446	--		--	
Upper terminus structure	5.0	100	5.0	100	5.0	100	5.0	100	--		--	
Tunnels	15.7	315	15.5	311	15.5	311	23.1	463	--		--	
Siphons	16.0	321	6.6	132	6.6	132	13.5	271				
Access Roads	56.0	1,272	58.2	1,322	71.5	1,624	69.0	1,568	41.8	950	41.8	950
Total O.M. and R.	2,008.4	38,680	2,027.4	39,065	2,055.9	39,751	2,059.9	39,861	1,823.6	35,234	1,829.9	35,359
Power and energy	19,249.7	284,627	19,341.0	285,966	19,266.0	284,861	19,222.8	284,241	19,499.4	286,676	19,417.8	284,960
TOTAL ANNUAL COST	21,258.1	323,307	21,368.4	325,031	21,321.9	324,612	21,282.7	324,102	21,323.0	321,910	21,247.7	320,319

a. Pastoria Two-Equal Lift.
b. Pastoria Two Lift.
c. Ridge-Pastoria Two Lift.
d. Ridge Two-Equal Lift.
e. Ridge Single Lift With Underground Discharge Lines.
f. Ridge Single Lift With Surface Discharge Lines.



STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT
TEHACHAPI DIVISION
ALTERNATIVE LIFT SYSTEMS
LOCATION AND VICINITY MAP
LOCATION MAP
PROJECT AREA
BAKERSFIELD
SANTA BARBARA
VENTURA
LOS ANGELES
SAN BERNARDINO
RIVERSIDE
SANTA ANA
VICINITY MAP
SCALE OF MILES
TEHACHAPI PUMPING PLANT
SOUTH SAN JOAQUIN DIVISION
TO BAKERSFIELD 30 MILES
GRAPEVINE ACCESS ROAD
GRAPEVINE
POWER LINE
BEARTRAP CANYON
ACCESS ROAD
CASTAC LAKE
TO FRAZIER PARK
KERN CO.
VENTURA CO.
LEBEC
TEJON PASS
GORMAN
LOS ANGELES CO.
VENTURA CO.
CARLEY V. PORTER TUNNEL
KERN CO.
LOS ANGELES CO.
COTTONWOOD POWER PLANT
ACCESS ROAD
QUAIL LAKE
OLD RIDGE ROUTE
TO LANCASTER 32 MILES
20 MI. TO CASTAIC

Plates 2 through 8 are bound

at the end of Book IV.

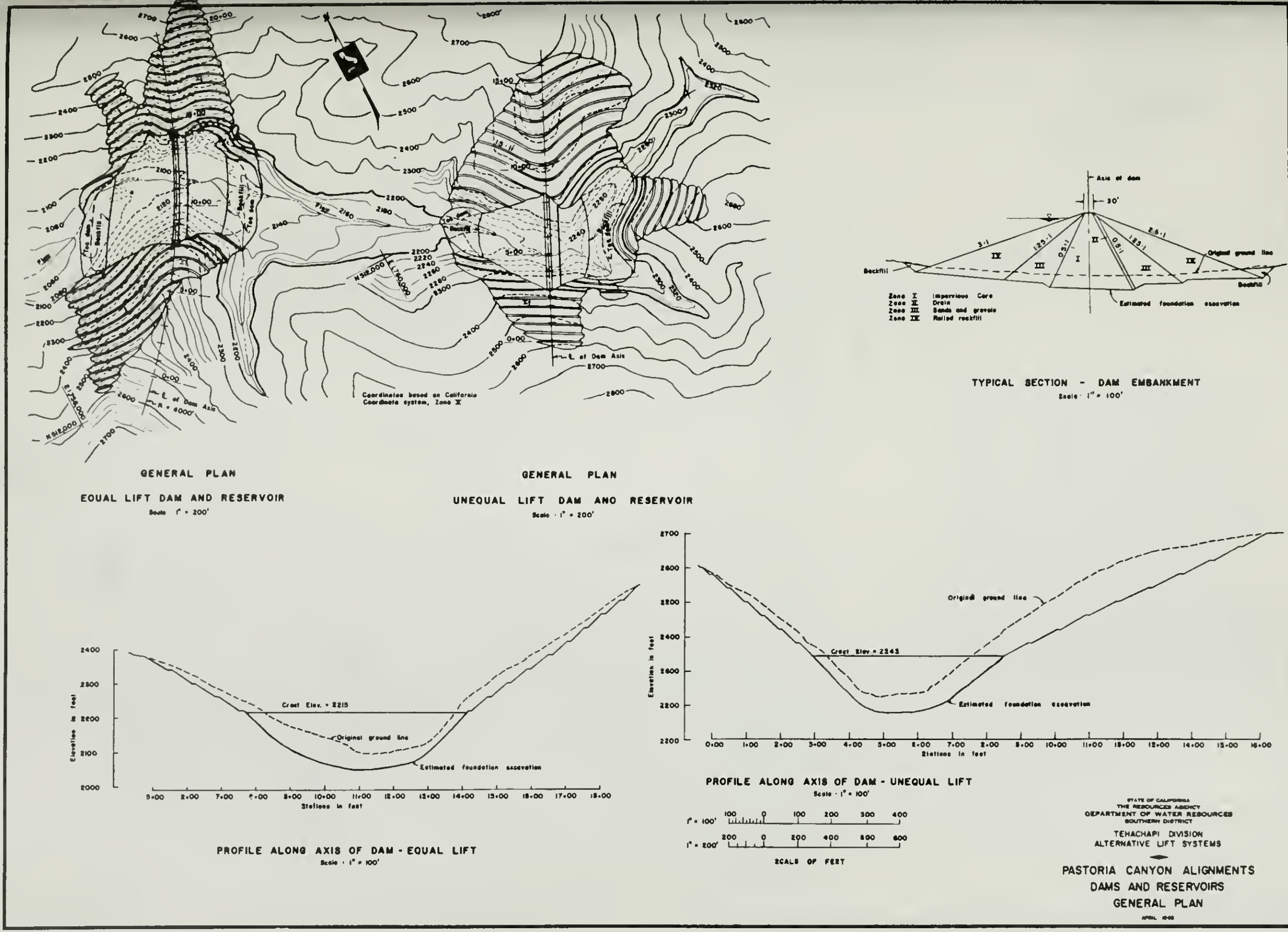
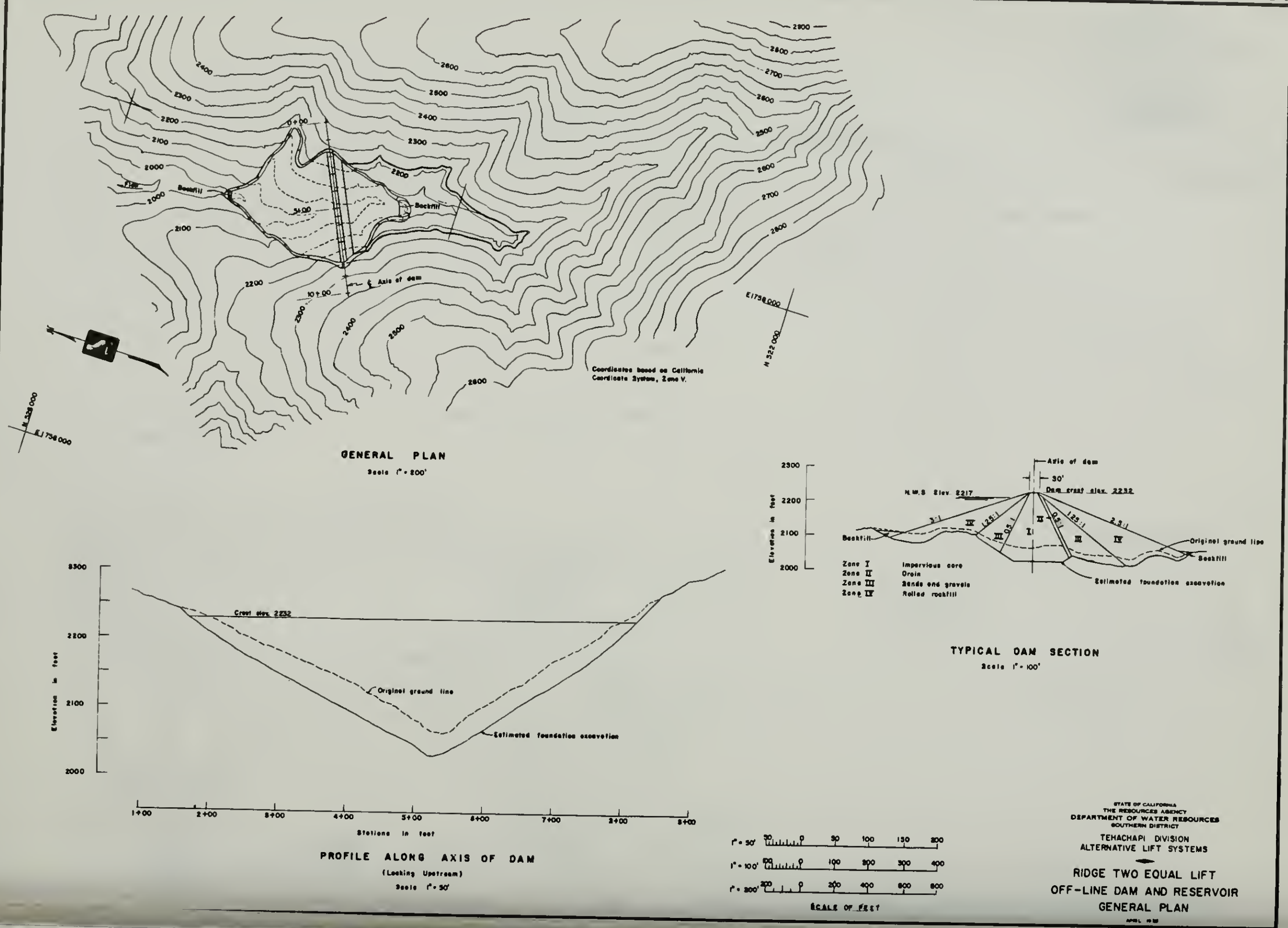
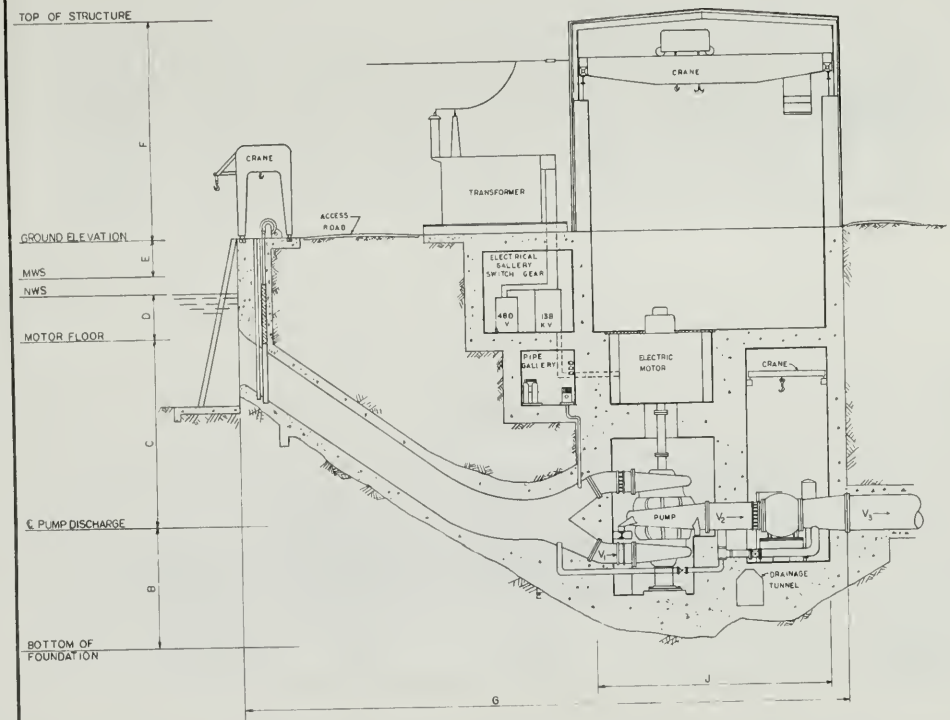

GENERAL PLAN
EQUAL LIFT DAM AND RESERVOIR
Scale 1" = 200'
GENERAL PLAN
UNEQUAL LIFT DAM AND RESERVOIR
Scale · 1" = 200'
Coordinates based on California Coordinate system, Zone V
TYPICAL SECTION - DAM EMBANKMENT
Scale · 1" = 100'
Axis of dam
Original ground line
Estimated foundation excavation
Backfill
Zone I Impervious Core
Zone II Drain
Zone III Sands and gravels
Zone IV Rolled rockfill
PROFILE ALONG AXIS OF DAM - EQUAL LIFT
Scale · 1" = 100'
Crest Elev. = 2215
Elevation in feet
Stations in feet
PROFILE ALONG AXIS OF DAM - UNEQUAL LIFT
Scale · 1" = 100'
Crest Elev. = 2343
SCALE OF FEET
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT
TEHACHAPI DIVISION
ALTERNATIVE LIFT SYSTEMS
PASTORIA CANYON ALIGNMENTS
DAMS AND RESERVOIRS
GENERAL PLAN

PLATE 10


GENERAL PLAN
Scale 1" = 200'
Backfill
Axis of dam
0+00
10+00
Coordinates based on California Coordinate System, Zone V.
E1758000
N 322000
PROFILE ALONG AXIS OF DAM
(Looking Upstream)
Scale 1" = 50'
Crest elev. 2232
Original ground line
Estimated foundation excavation
Elevation in feet
Stations in feet
TYPICAL DAM SECTION
Scale 1" = 100'
Axis of dam
30'
N.W.S. Elev. 2217
Dam crest elev. 2232
Original ground line
Backfill
Estimated foundation excavation
Zone I Impervious core
Zone II Drain
Zone III Sands and gravels
Zone IV Rolled rockfill
SCALE OF FEET
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT
TEHACHAPI DIVISION
ALTERNATIVE LIFT SYSTEMS
RIDGE TWO EQUAL LIFT
OFF-LINE DAM AND RESERVOIR
GENERAL PLAN

NOTE THIS SECTION APPLICABLE TO STATION "A"
SYSTEM 1 (PASTORIA TWO EQUAL LIFT)
SYSTEM 2 (PASTORIA TWO LIFT)
SYSTEM 3 (RIDGE/PASTORIA TWO LIFT)
SYSTEM 4 (RIDGE TWO EQUAL LIFT)
AND STATION "B"
SYSTEM 1 (PASTORIA TWO EQUAL LIFT)
SYSTEM 2 (PASTORIA TWO LIFT)
SYSTEM 3 (RIDGE/PASTORIA TWO LIFT)



PLANT DATA	ALT 4 2 EQUAL LIFT		ALT 3 2UNEQUAL LIFT		ALT 2 2UNEQUAL LIFT		ALT 1 2 EQUAL LIFT	
	STA A RIDGE	STA B RIDGE	STA A RIDGE	STA B PAS TORIA	STA A PAS-TORIA	STA B PAS-TORIA	STA A PAS-TORIA	STA B PAS-TORIA
TOTAL Q CFS	4093	SEE PLATE 15	4093	4093	4093	4093	4093	4093
T D HEAD FT	9881		11158	8574	11235	8574	9954	9836
NO OF UNITS	8		8	8	8	8	8	8
Q/UNIT CFS	512		512	512	512	512	512	512
UNIT HP	62300		70600	54200	71100	54200	62700	62000
RPM	600		600	514	600	514	600	600
NO OF STAGES	2		2	2	2	2	2	2
N_s SPECIFIC SPEED	1940		1770	1830	1760	1830	1930	1980
S SUCTION SPECIFIC SPEED	7000		7000	7000	7000	7000	7000	7000
Z SUBMERGENCE	61		61	56	61	56	62	69
D_2 IMPELLER DIAMETER FT	67		69	72	69	72	67	66
V_1 FT/SEC	167		167	167	167	167	167	167
V_2 "	200		200	200	200	200	200	200
V_3 "	154		154	154	154	154	154	154
DIMENSIONS								
B FT	27		27	27	27	27	27	27
C "	41		41	41	41	41	41	41
D "	20		21	17	22	19	13	29
E "	5		5	5	5	5	3	3
F "	49		49	49	49	49	49	49
G "	127		128	128	128	128	127	127
J "	49		50	50	50	50	49	49

STATE OF CALIFORNIA
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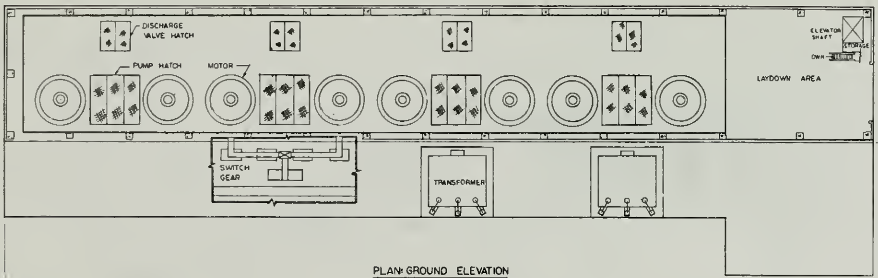
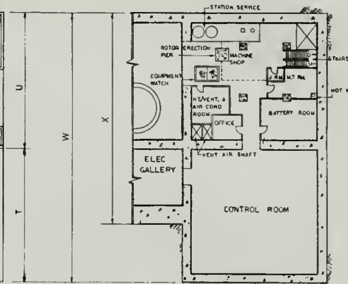
TEHACHAPI DIVISION
ALTERNATIVE LIFT SYSTEMS

TWO LIFT SYSTEM
PUMPING PLANT
TRANSVERSE SECTION
INTAKE FROM POOL
APRIL 1969

PLATE 12

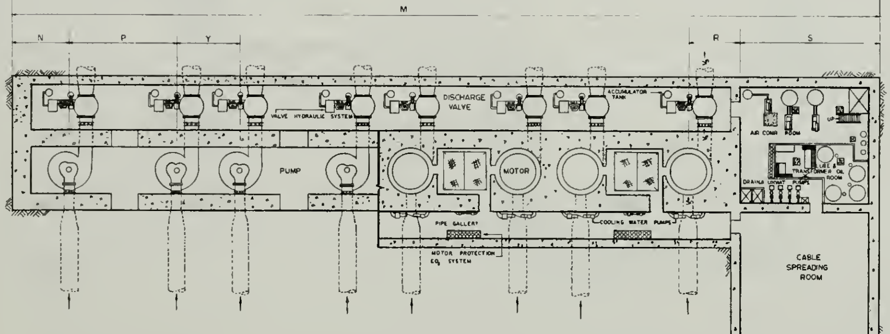


PLAN: GROUND ELEVATION



PLAN: MOTOR FLOOR

PLANT DATA	ALT 4 2 EQUAL LIFT STA A RIDGE	ALT 4 2 EQUAL LIFT STA B RIDGE	ALT 3 2-UNEQUAL-LIFT STA A RIDGE	ALT 3 2-UNEQUAL-LIFT STA B PAS-TORIA	ALT 2 2-UNEQUAL-LIFT STA A PAS-TORIA	ALT 2 2-UNEQUAL-LIFT STA B PAS-TORIA	ALT 1 2 EQUAL LIFT STA A PAS-TORIA	ALT 1 2 EQUAL LIFT STA B PAS-TORIA
TOTAL Q, CFS	4093	SEE PLATE 14	4093	4093	4093	4093	4093	4093
T.D. HEAD, FT	9881		11158	8574	11235	8574	9954	9836
NO. OF UNITS	8		8	8	8	8	8	8
Q/UNIT, CFS	512		512	512	512	512	512	512
UNIT HP	62300		70600	54200	71100	54200	62700	62000
RPM	600		600	514	600	514	600	600
NO. OF STAGES	2		2	2	2	2	2	2
N_s- SPECIFIC SPEED	1940		1720	1850	1760	1850	1930	1950
S- SUCTION SPECIFIC SPEED	7000		7000	7000	7000	7000	7000	7000
Z- SUBMERGENCE	61		61	56	61	56	62	69
D_2 IMPELLER DIAMETER, FT	6.7		6.9	7.2	6.9	7.2	6.7	6.6
V_1 FT/SEC	16.7		16.7	16.7	16.7	16.7	16.7	16.7
V_2 "	20.0		20.0	20.0	20.0	20.0	20.0	20.0
V_3 "	15.4		15.4	15.4	15.4	15.4	15.4	15.4
DIMENSIONS								
M FT	386		391	391	391	391	386	386
N "	25		26	26	26	26	25	25
P "	48		48	48	48	48	48	48
R "	23		24	24	24	24	24	24
S "	62		62	62	62	62	62	62
T "	58		58	58	58	58	58	58
U "	57		58	58	58	58	57	57
W "	115		116	116	116	116	115	115
X "	90		91	91	91	91	90	90
Y "	28		29	29	29	29	28	28



PLAN: PUMP & GALLERY FLOORS

NOTE THESE PLANS APPLICABLE TO STATION "A"
SYSTEM 1 (PASTORIA TWO EQUAL LIFT)
SYSTEM 2 (PASTORIA TWO LIFT)
SYSTEM 3 (RIDGE/PASTORIA TWO LIFT)
SYSTEM 4 (RIDGE TWO EQUAL LIFT)
AND STATION "B"
SYSTEM 1 (PASTORIA TWO EQUAL LIFT)
SYSTEM 2 (PASTORIA TWO LIFT)
SYSTEM 3 (RIDGE/PASTORIA TWO LIFT)

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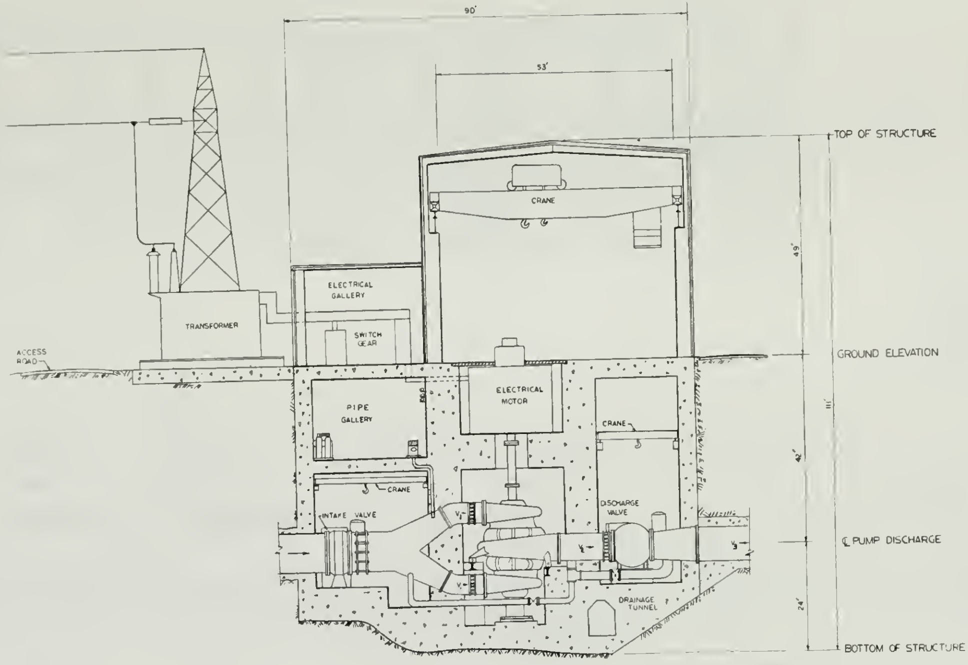
ALTERNATIVE LIFT SYSTEMS

TWO LIFT SYSTEM
PUMPING PLANT
PLAN
INTAKE FROM POOL
APRIL 1965



NOTE THIS SECTION APPLICABLE TO STATION "B" SYSTEM 4 (RIDGE TWO EQUAL LIFT) ONLY

PLANT DATA

TOTAL Q, CFS	4093
T D HEAD, FT	9881
NO OF UNITS	8
Q/UNIT, CFS	512
UNIT HP	62,300
RPM	600
NO OF STAGES	2
N_s SPECIFIC SPEED	1940
S-SUCTION SPECIFIC SPEED	7000
Z SUBMERGENCE FT	75
D_1 IMPELLER DIAMETER, FT	67
V FPS	167
V_1 "	200
V_3 "	154

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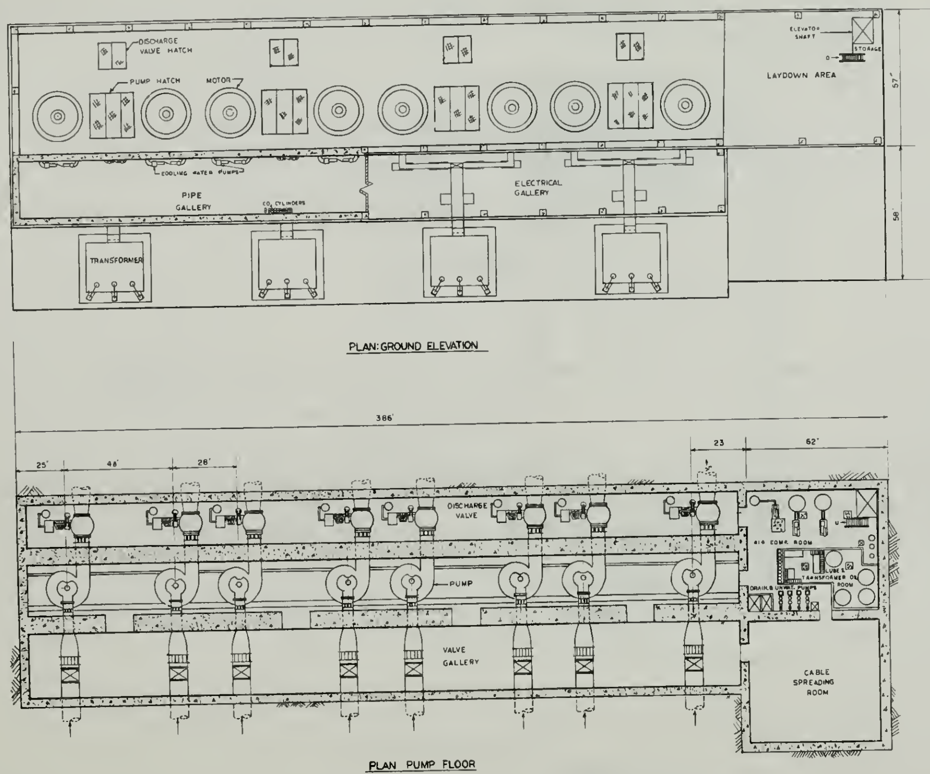
SOUTHERN DISTRICT

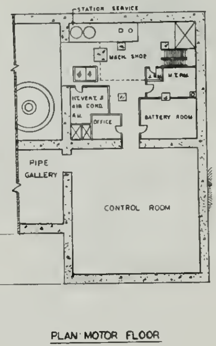
TEHACHAPI DIVISION
ALTERNATIVE LIFT SYSTEMS

TWO LIFT SYSTEM
PUMPING PLANT
TRANSVERSE SECTION
INTAKE FROM MANIFOLD

APRIL 1965

PLATE 14





NOTE: THESE PLANS APPLICABLE TO STATION "B" SYSTEM 4 (RIDGE TWO EQUAL LIFT) ONLY

PLANT DATA

TOTAL Q, CFS	4093
TD HEAD, FT	988.1
NO OF UNITS	8
Q/UNIT, CFS	512
UNIT HP	62,300
RPM	600
NO OF STAGES	2
N-SPECIFIC SPEED	1940
S-SUCTION SPECIFIC SPEED	7000
Z-SUBMERGENCE,	75
D_2-IMPELLER DIAMETER	67
V_1 FPS	16.7
V_2 "	20.0
V_3 "	15.4

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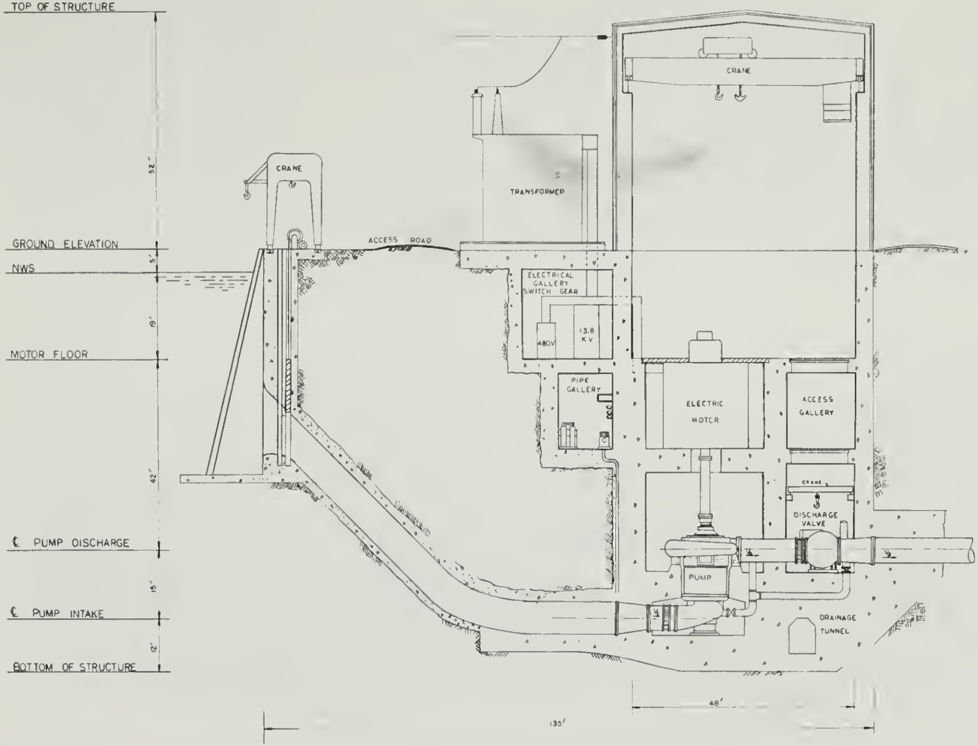
SOUTHERN DISTRICT

TEHACHAPI DIVISION
ALTERNATIVE LIFT SYSTEMS

TWO LIFT SYSTEM
PUMPING PLANT
PLAN
INTAKE FROM MANIFOLD
APRIL 1966



PLANT DATA	ALT. 5 SINGLE LIFT RIDGE	ALT 6 SINGLE LIFT RIDGE
TOTAL Q CFS	4093	4093
T.D HEAD FT.	1983.2	1974.5
NO. OF UNITS	14	14
Q/UNIT CFS	292.4	292.4
UNIT HP	72,200	71,900
RPM	600	600
NO OF STAGES	4	4
N_s SPECIFIC SPEED	2,070	2,060
S-SUCTION SPECIFIC SPEED	7000	7000
Z-SUBMERGENCE FT.	71	71
D IMPELLER DIAM FT	6.2	6.2
V_1 FT/SEC	16	16
V_2 FT/SEC	20	20
V_3 FT/SEC	18.1	16.7

STATE OF CALIFORNIA
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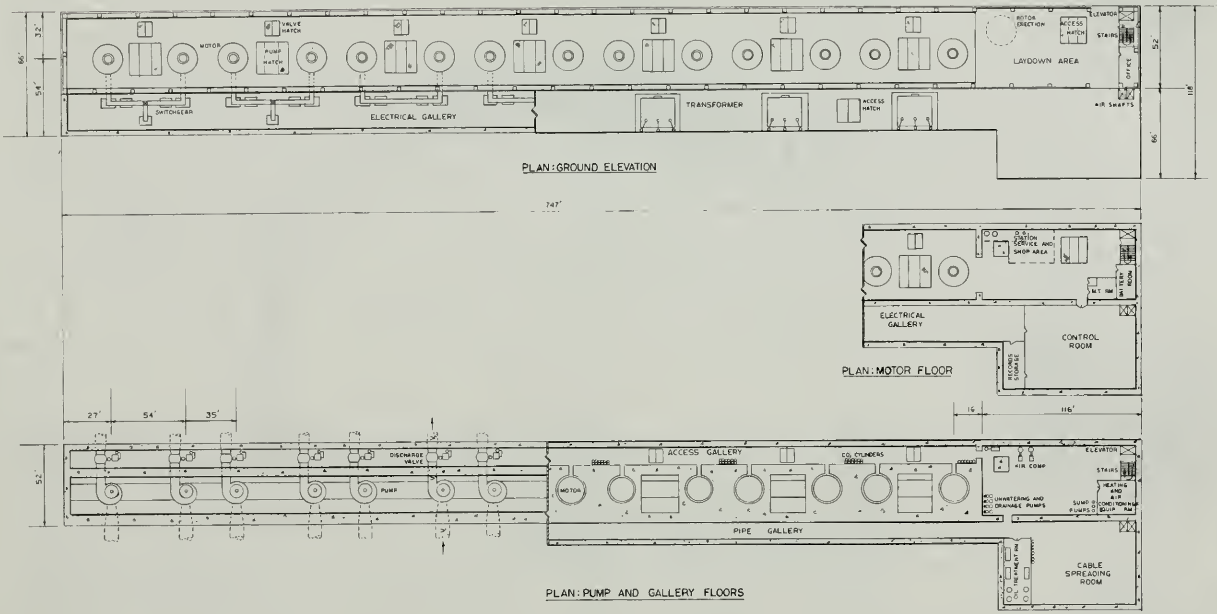
SOUTHERN DISTRICT

TEHACHAPI DIVISION
ALTERNATIVE LIFT SYSTEMS

SINGLE LIFT SYSTEM
PUMPING PLANT
TRANSVERSE SECTION
INTAKE FROM POOL
APRIL 1965



PLANT DATA	ALT 5 SINGLE LIFT RIDGE	ALT 6 SINGLE LIFT RIDGE
TOTAL Q cfs	4093	4093
T D HEAD ft	1963.2	1974.5
NO OF UNITS	14	14
Q/UNIT cfs	292.4	292.4
UNIT HP	72,200	71,900
RPM	600	600
NO OF STAGES	4	4
N_s SPECIFIC SPEED	2070	2080
S-SUCTION SPECIFIC SPEED	7000	7000
Z-SUBMERGENCE ft	71	71
D_2 IMPELLER DIA ft	6.2	6.2
V_1 fps	16	16
V_2 fps	20	20
V_3 fps	181	167

STATE OF CALIFORNIA
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SOUTHERN DISTRICT

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ALTERNATIVE LIFT SYSTEMS

SINGLE LIFT SYSTEM
PUMPING PLANT
PLAN
INTAKE FROM POOL

APRIL 1963

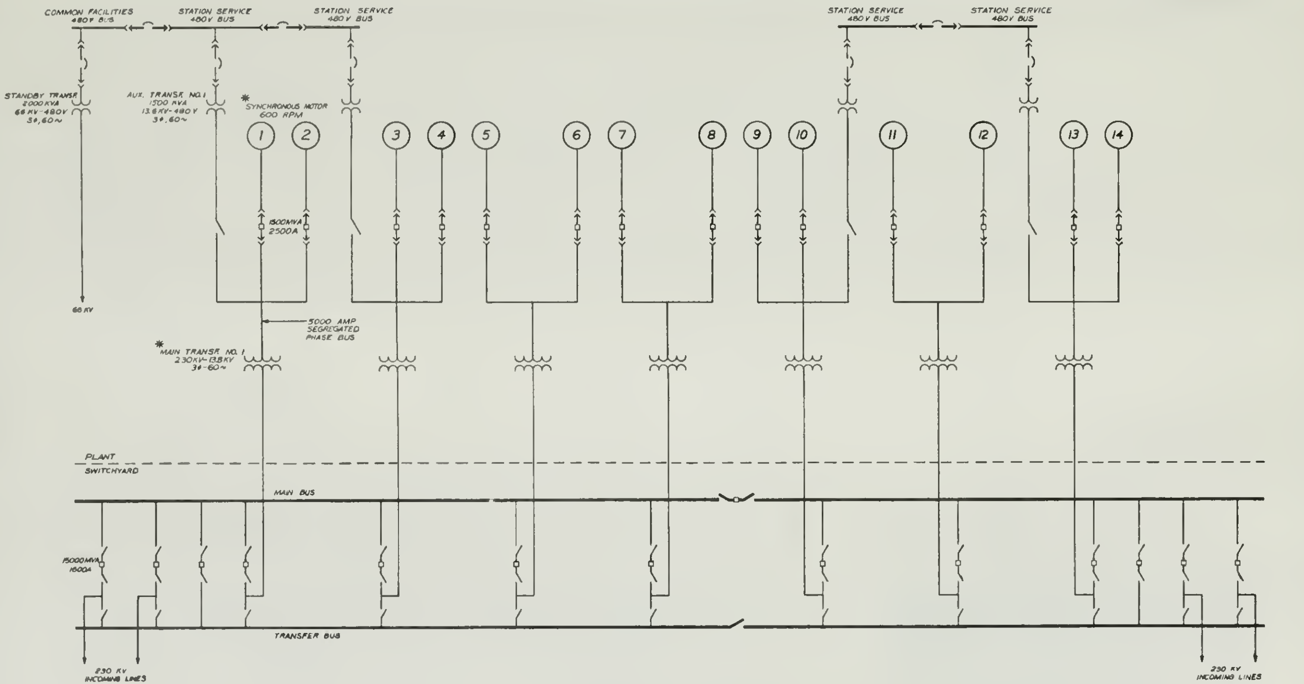

*TABLE OF ELECTRICAL EQUIPMENT RATING

SCHEME NO.	PUMP MOTOR H.P.	MAIN TRANSF. MVA
5	72,200	112
8	71,900	112

STATE OF CALIFORNIA
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TEHACHAPI DIVISION
ALTERNATIVE LIFT SYSTEMS

SINGLE LIFT SYSTEM
ELECTRICAL SINGLE LINE DIAGRAM

APRIL 1963

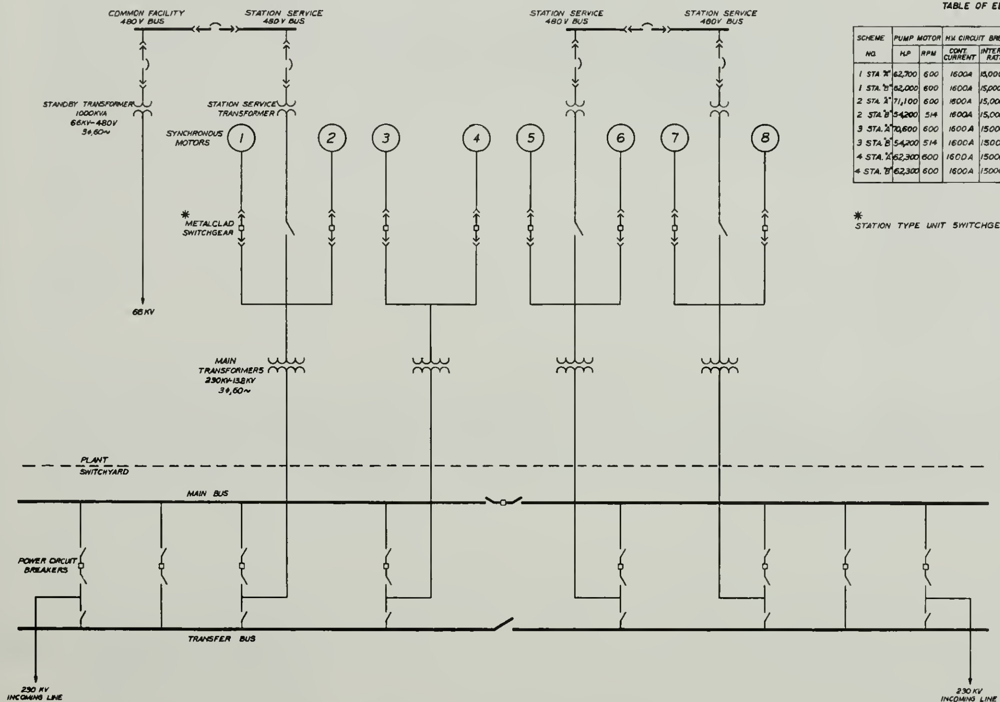

TABLE OF ELECTRICAL EQUIPMENT RATING

SCHEME	PUMP MOTOR		H.V. CIRCUIT BREAKER		MAIN	UNIT SWITCHGEAR		BUS	STATION
NO.	H.P.	RPM	CONT. CURRENT	INTERRUPT. RATING	TRANSF.	CONT. CURRENT	INTERRUPT RATING	CAPACITY	SERVICE TRANSF.
1 STA. "A"	62,700	600	1600A	15,000MVA	98MVA	2000 A	1000MVA	4000A	750KVA
1 STA. "B"	62,000	600	1600A	15,000MVA	96MVA	2000A	1000MVA	4000A	750KVA
2 STA. "A"*	71,100	600	1600A	15,000MVA	111 MVA	2500A	1500 MVA	5000A	750KVA
2 STA. "B"	54,200	514	1600A	15,000MVA	84MVA	2000A	1000 MVA	4000A	750KVA
3 STA. "A"*	70,600	600	1600 A	15000MVA	110MVA	2500A	1500 MVA	5000 A	750 KVA
3 STA. "B"	54,200	514	1600A	15000MVA	84MVA	2000A	1000 MVA	4000A	750 KVA
4 STA. "A"	62,300	600	1600A	15000MVA	97MVA	2000A	1000 MVA	4000A	750KVA
4 STA. "B"	62,300	600	1600A	15000MVA	97MVA	2000A	1000 MVA	4000 A	750KVA

* STATION TYPE UNIT SWITCHGEAR FOR SCHEME NO. 2,3 STA. "A" ONLY.

STATE OF CALIFORNIA
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SOUTHERN DISTRICT

TEHACHAPI DIVISION
ALTERNATIVE LIFT SYSTEMS

TWO LIFT SYSTEM
ELECTRICAL SINGLE LINE DIAGRAM

Plates 19 through 22 are bound

at the end of Book IV.

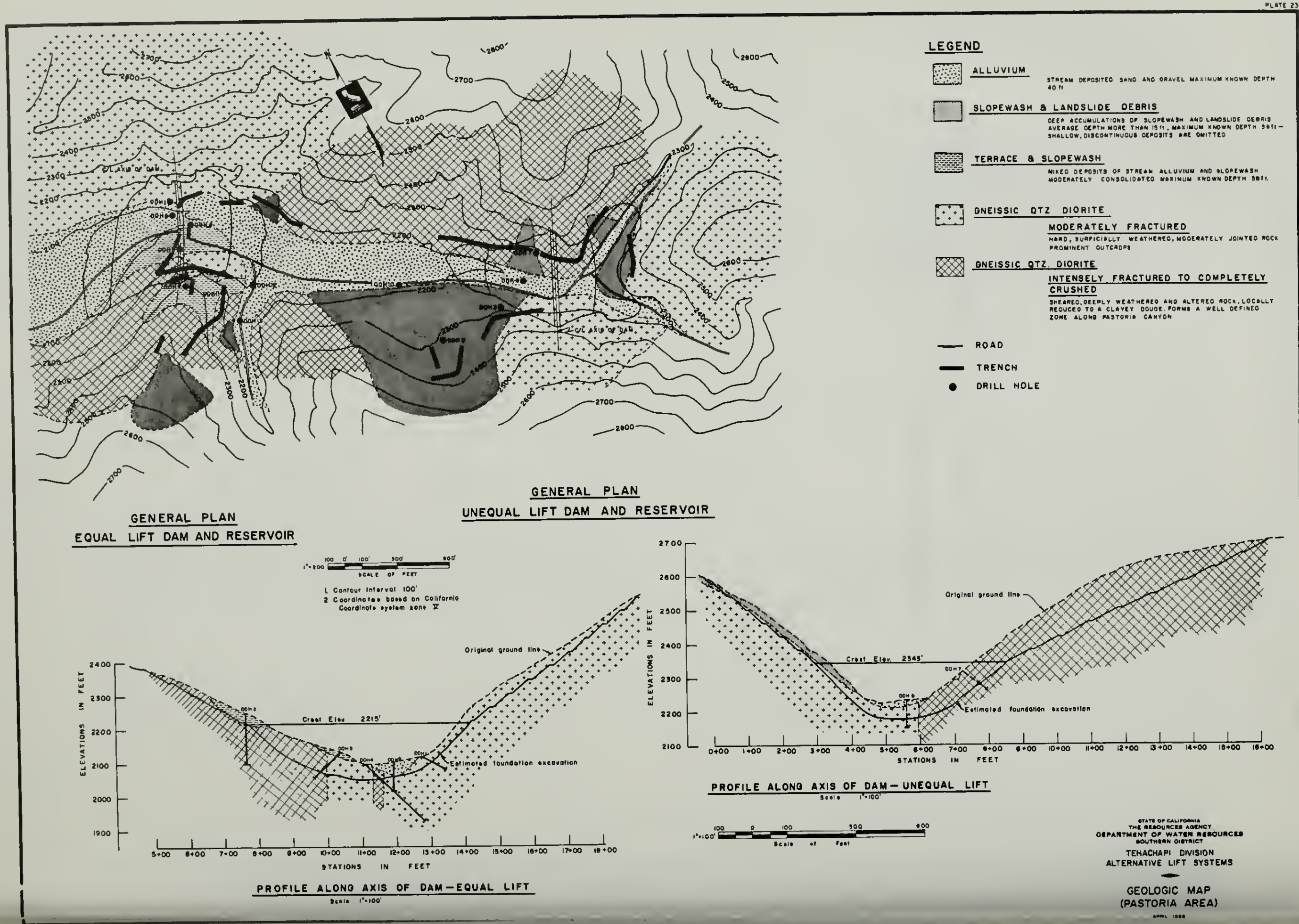
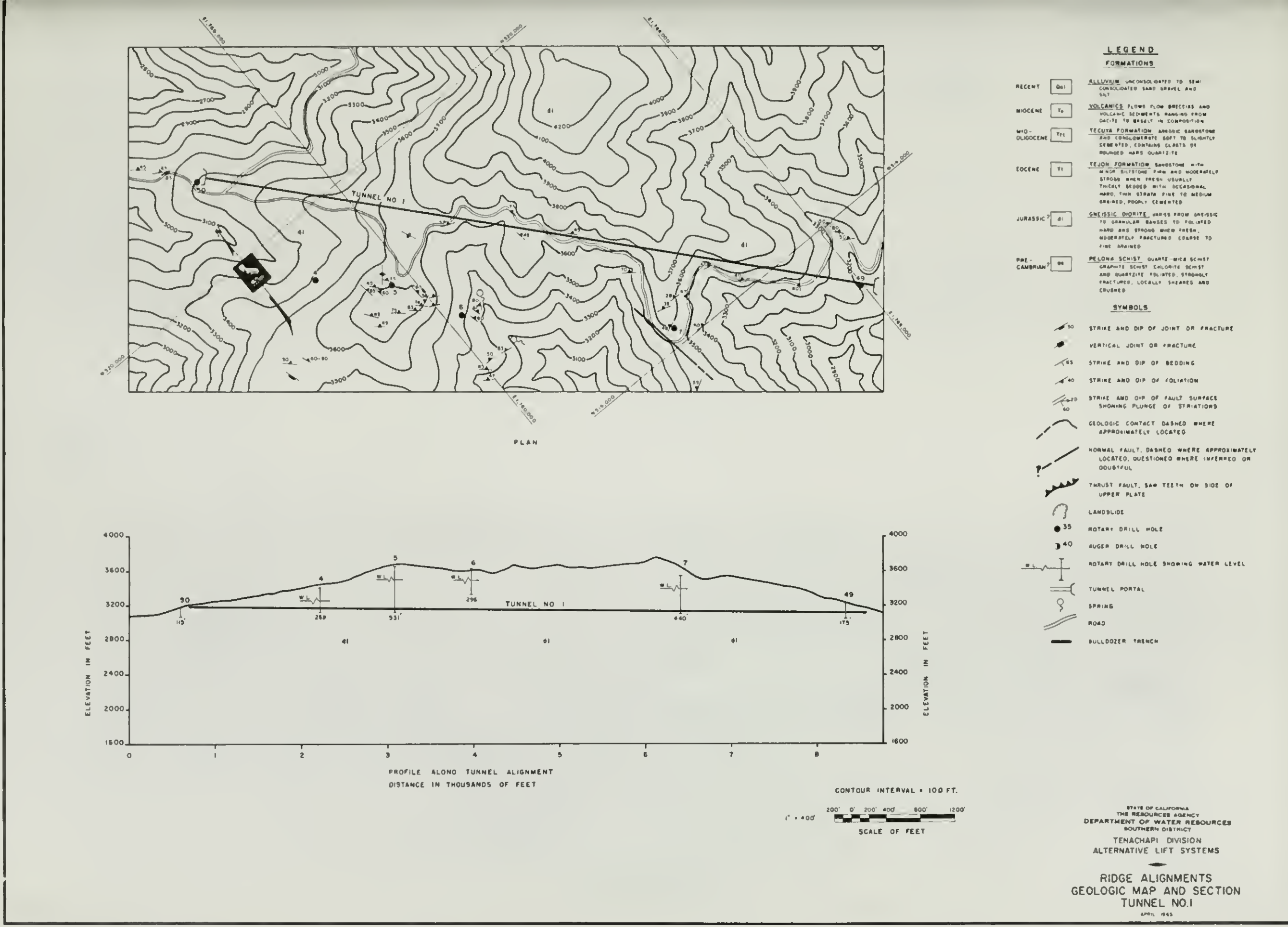
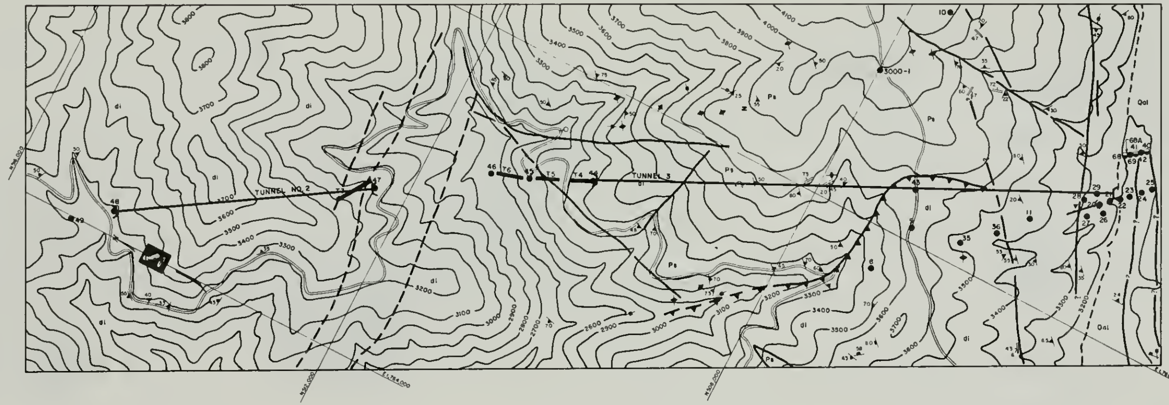
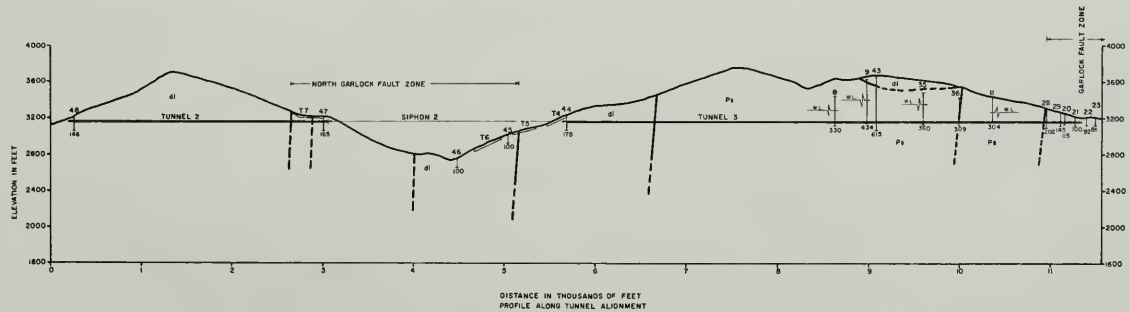


PLATE 23
LEGEND
ALLUVIUM
STREAM DEPOSITED SAND AND GRAVEL MAXIMUM KNOWN DEPTH 40 ft
SLOPEWASH & LANDSLIDE DEBRIS
DEEP ACCUMULATIONS OF SLOPEWASH AND LANDSLIDE DEBRIS AVERAGE DEPTH MORE THAN 15 ft, MAXIMUM KNOWN DEPTH 38 ft — SHALLOW, DISCONTINUOUS DEPOSITS ARE OMITTED
TERRACE & SLOPEWASH
MIXED DEPOSITS OF STREAM ALLUVIUM AND SLOPEWASH MODERATELY CONSOLIDATED MAXIMUM KNOWN DEPTH 38 ft.
GNEISSIC QTZ DIORITE
MODERATELY FRACTURED
HARD, SUPERFICIALLY WEATHERED, MODERATELY JOINTED ROCK PROMINENT OUTCROPS
GNEISSIC QTZ. DIORITE
INTENSELY FRACTURED TO COMPLETELY CRUSHED
SHEARED, DEEPLY WEATHERED AND ALTERED ROCK, LOCALLY REDUCED TO A CLAYEY GOUGE. FORMS A WELL DEFINED ZONE ALONG PASTORIA CANYON
ROAD
TRENCH
DRILL HOLE
GENERAL PLAN
EQUAL LIFT DAM AND RESERVOIR
GENERAL PLAN
UNEQUAL LIFT DAM AND RESERVOIR
SCALE OF FEET
1. Contour Interval 100'
2. Coordinates based on California Coordinate system zone V
Original ground line
Crest Elev. 2215'
Estimated foundation excavation
ELEVATIONS IN FEET
STATIONS IN FEET
PROFILE ALONG AXIS OF DAM — EQUAL LIFT
Scale 1"=100'
Crest Elev. 2343'
PROFILE ALONG AXIS OF DAM — UNEQUAL LIFT
Scale 1"=100'
Scale of Feet
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT
TEHACHAPI DIVISION
ALTERNATIVE LIFT SYSTEMS
GEOLOGIC MAP
(PASTORIA AREA)


PLAN
TUNNEL NO 1
PROFILE ALONG TUNNEL ALIGNMENT
DISTANCE IN THOUSANDS OF FEET
ELEVATION IN FEET
CONTOUR INTERVAL = 100 FT.
1" = 400'
SCALE OF FEET
LEGEND
FORMATIONS
RECENT Qal ALLUVIUM UNCONSOLIDATED TO SEMI CONSOLIDATED SAND GRAVEL AND SILT
MIOCENE Tv VOLCANICS FLOWS FLOW BRECCIAS AND VOLCANIC SEDIMENTS RANGING FROM DACITE TO BASALT IN COMPOSITION
MIO-OLIGOCENE Ttc TECUYA FORMATION ARKOSIC SANDSTONE AND CONGLOMERATE SOFT TO SLIGHTLY CEMENTED, CONTAINS CLASTS OF ROUNDED HARD QUARTZITE
EOCENE Tt TEJON FORMATION SANDSTONE WITH MINOR SILTSTONE FIRM AND MODERATELY STRONG WHEN FRESH USUALLY THICKLY BEDDED WITH OCCASIONAL HARD, THIN STRATA FINE TO MEDIUM GRAINED, POORLY CEMENTED
JURASSIC? di GNEISSIC DIORITE VARIES FROM GNEISSIC TO GRANULAR RANGES TO FOLIATED HARD AND STRONG WHEN FRESH, MODERATELY FRACTURED COARSE TO FINE GRAINED
PRE-CAMBRIAN? ps PELONA SCHIST QUARTZ-MICA SCHIST GRAPHITE SCHIST CHLORITE SCHIST AND QUARTZITE FOLIATED, STRONGLY FRACTURED, LOCALLY SHEARED AND CRUSHED
SYMBOLS
STRIKE AND DIP OF JOINT OR FRACTURE
VERTICAL JOINT OR FRACTURE
STRIKE AND DIP OF BEDDING
STRIKE AND DIP OF FOLIATION
STRIKE AND DIP OF FAULT SURFACE SHOWING PLUNGE OF STRIATIONS
GEOLOGIC CONTACT DASHED WHERE APPROXIMATELY LOCATED
NORMAL FAULT, DASHED WHERE APPROXIMATELY LOCATED, QUESTIONED WHERE INFERRED OR DOUBTFUL
THRUST FAULT, SAW TEETH ON SIDE OF UPPER PLATE
LANDSLIDE
ROTARY DRILL HOLE
AUGER DRILL HOLE
ROTARY DRILL HOLE SHOWING WATER LEVEL
TUNNEL PORTAL
SPRING
ROAD
BULLDOZER TRENCH
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT
TEHACHAPI DIVISION
ALTERNATIVE LIFT SYSTEMS
RIDGE ALIGNMENTS
GEOLOGIC MAP AND SECTION
TUNNEL NO.1





SCALE OF FEET 0 200 400 800

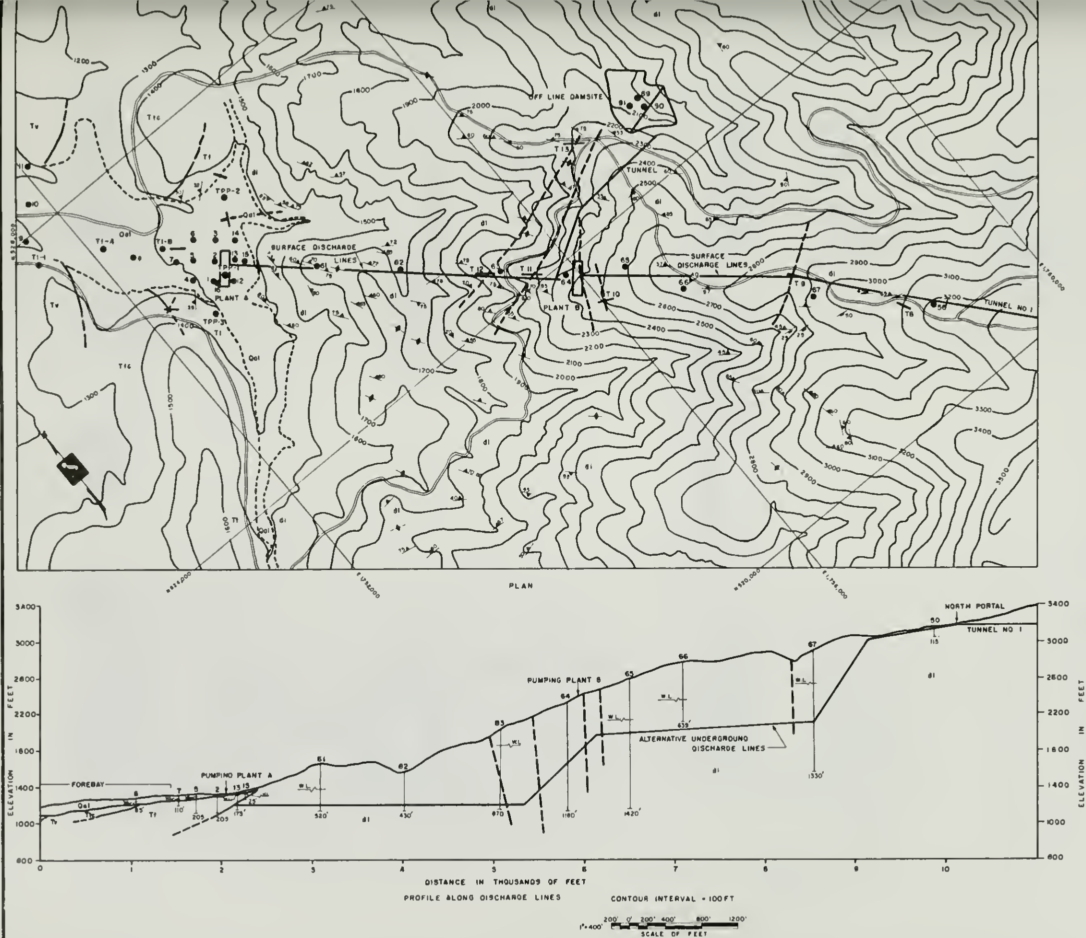
CONTOUR INTERVAL = 100'

SEE PLATE 24 FOR LEGEND

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT

TEHACHAPI DIVISION
ALTERNATIVE LIFT SYSTEMS

RIDGE ALIGNMENTS
GEOLOGIC MAP AND SECTION
TUNNELS NO. 2 AND 3



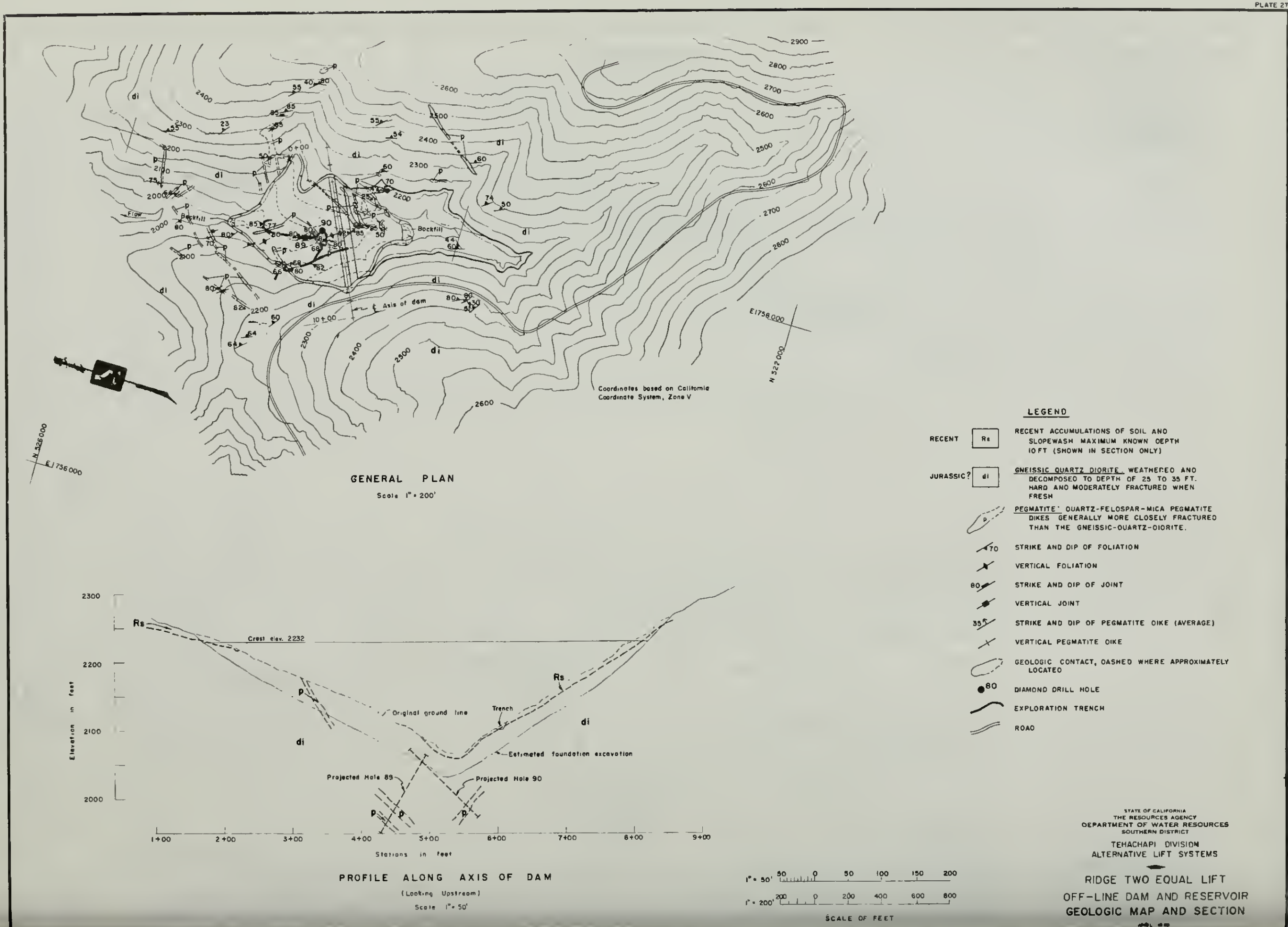
SEE PLATE NO 24 FOR LEGEND

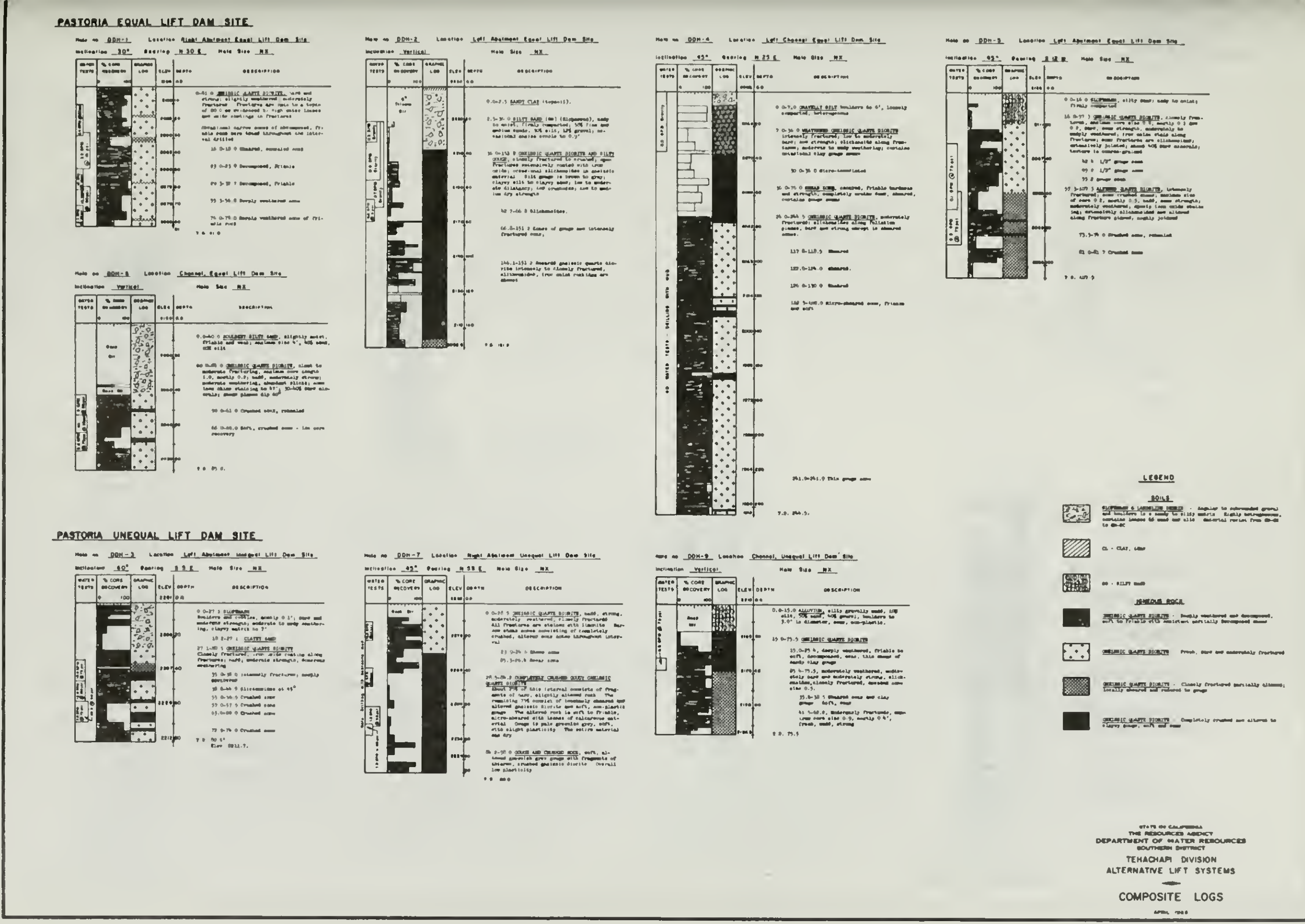
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT

TEHACHAPI DIVISION
ALTERNATIVE LIFT SYSTEMS

RIDGE ALIGNMENTS
GEOLOGIC MAP AND SECTION
PLANTS AND DISCHARGE LINES

APRIL 1963


GENERAL PLAN
Scale 1" = 200'
Coordinates based on California Coordinate System, Zone V
Axis of dam
Backfill
Flow
E1758,000
N 522,000
E1756,000
N 525,000
PROFILE ALONG AXIS OF DAM
(Looking Upstream)
Scale 1" = 50'
Crest elev. 2232
Original ground line
Trench
Estimated foundation excavation
Projected Hole 89
Projected Hole 90
Stations in feet
Elevation in feet
LEGEND
RECENT
RECENT ACCUMULATIONS OF SOIL AND SLOPEWASH MAXIMUM KNOWN DEPTH 10 FT (SHOWN IN SECTION ONLY)
JURASSIC?
GNEISSIC QUARTZ DIORITE. WEATHERED AND DECOMPOSED TO DEPTH OF 25 TO 35 FT. HARD AND MODERATELY FRACTURED WHEN FRESH
PEGMATITE: QUARTZ-FELDSPAR-MICA PEGMATITE DIKES GENERALLY MORE CLOSELY FRACTURED THAN THE GNEISSIC-QUARTZ-DIORITE.
STRIKE AND DIP OF FOLIATION
VERTICAL FOLIATION
STRIKE AND DIP OF JOINT
VERTICAL JOINT
STRIKE AND DIP OF PEGMATITE DIKE (AVERAGE)
VERTICAL PEGMATITE DIKE
GEOLOGIC CONTACT, DASHED WHERE APPROXIMATELY LOCATED
DIAMOND DRILL HOLE
EXPLORATION TRENCH
ROAD
SCALE OF FEET
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT
TEHACHAPI DIVISION
ALTERNATIVE LIFT SYSTEMS
RIDGE TWO EQUAL LIFT
OFF-LINE DAM AND RESERVOIR
GEOLOGIC MAP AND SECTION


PASTORIA EQUAL LIFT DAM SITE
PASTORIA UNEQUAL LIFT DAM SITE
LEGEND
SOILS
IGNEOUS ROCK
DEPARTMENT OF WATER RESOURCES
TEHACHAPI DIVISION
ALTERNATIVE LIFT SYSTEMS
COMPOSITE LOGS

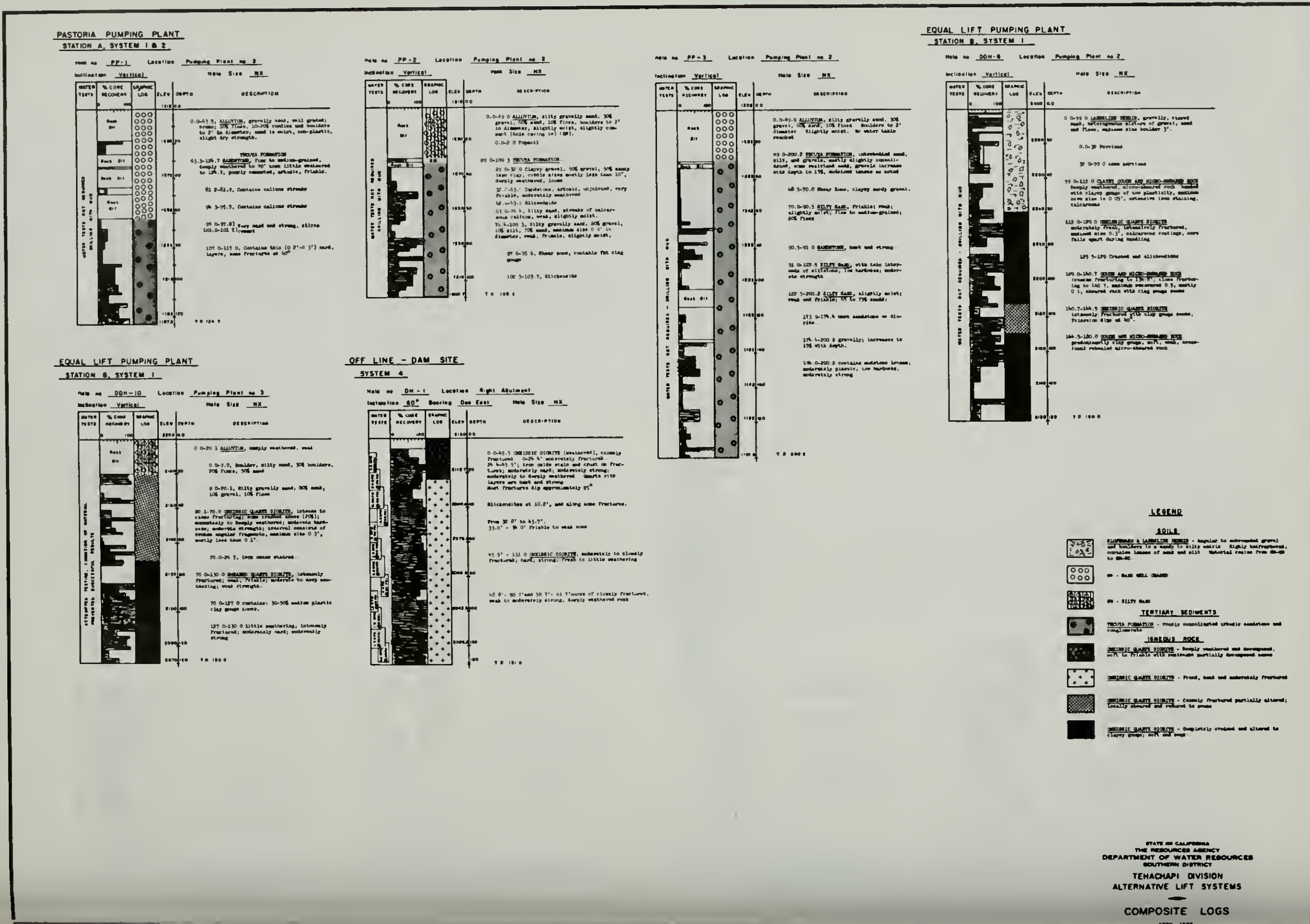

PASTORIA PUMPING PLANT
STATION A, SYSTEM 1 & 2
EQUAL LIFT PUMPING PLANT
STATION B, SYSTEM 1
OFF LINE - DAM SITE
SYSTEM 4
EQUAL LIFT PUMPING PLANT
STATION B, SYSTEM 1
LEGEND
SOILS
TERTIARY SEDIMENTS
IGNEOUS ROCK
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT
TEHACHAPI DIVISION
ALTERNATIVE LIFT SYSTEMS
COMPOSITE LOGS

Plate 30 is bound at the end of Book IV.

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APPENDIX A

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APPENDIX B

Photographs of Sites

STATION A PUMPING PLANT SITE
IN PASTORIA CANYON ALIGNMENTS

B-1

VIEW LOOKING DOWN CANYON AT SITE
OF DAM IN PASTORIA TWO EQUAL LIFT
SYSTEM

VIEW OF LEFT ABUTMENT OF DAM AND
STATION B PUMPING PLANT SITE OF
PASTORIA TWO EQUAL LIFT SYSTEM

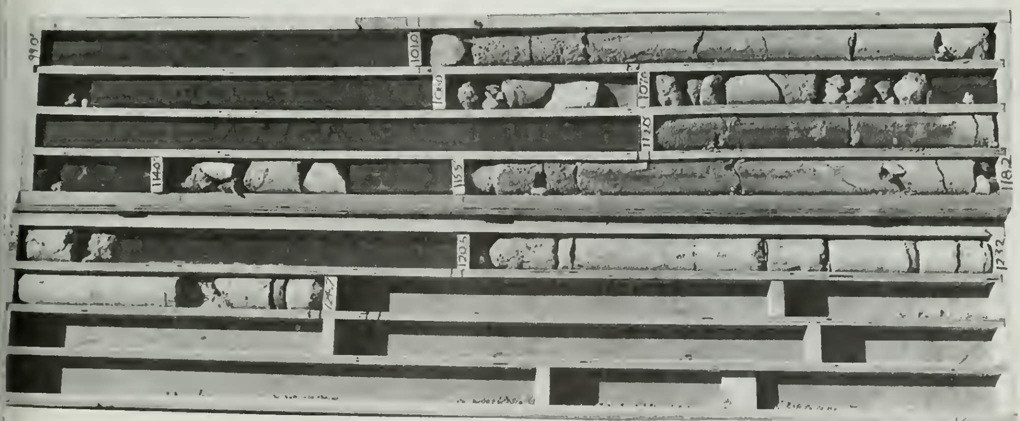
VIEW LOOKING UP CANYON, AT SITE OF
DAM AND STATION B PUMPING PLANT
IN PASTORIA AND RIDGE-PASTORIA
TWO LIFT SYSTEMS

SINGLE LIFT, OR STATION A OF TWO LIFT
SYSTEMS, PLANT AND INTAKE CHANNEL
SITE. VIEW LOOKING UP RIDGE

LOOKING UP CANYON AT SITE OF OFF-LINE
DAM OF RIDGE TWO EQUAL LIFT SYSTEM.
EXPLORATION TRENCHES NEAR BOTTOM OF
CANYON ARE AT AXIS OF EMBANKMENT

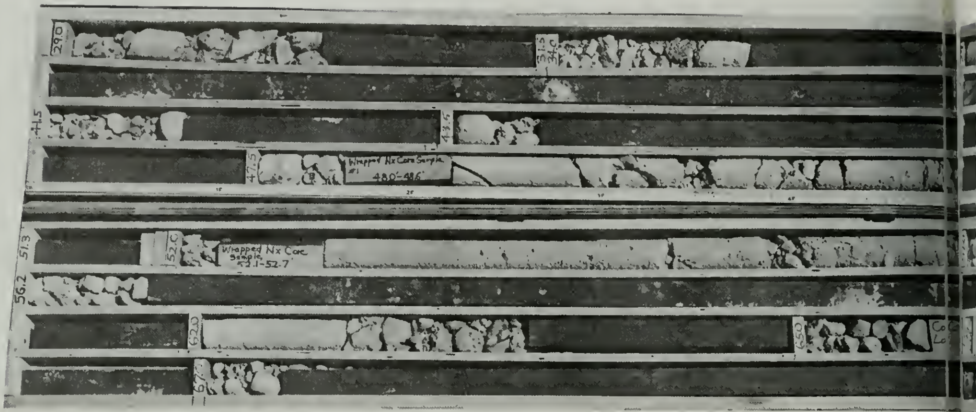
APPENDIX C

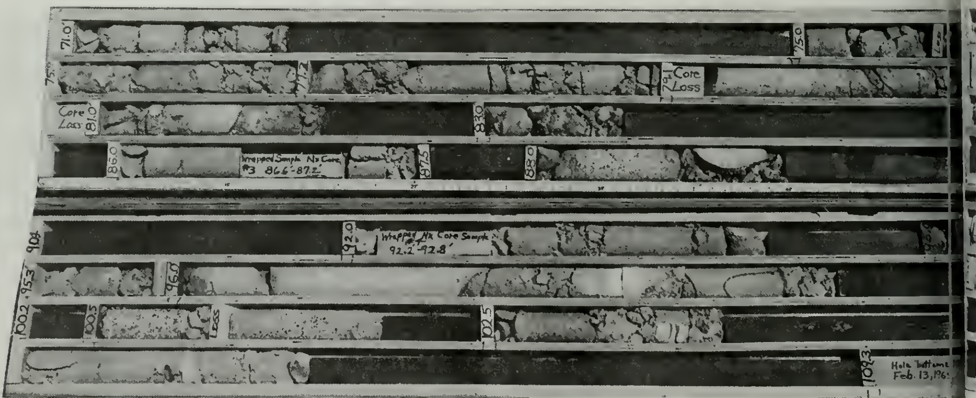
Photographs of Cores



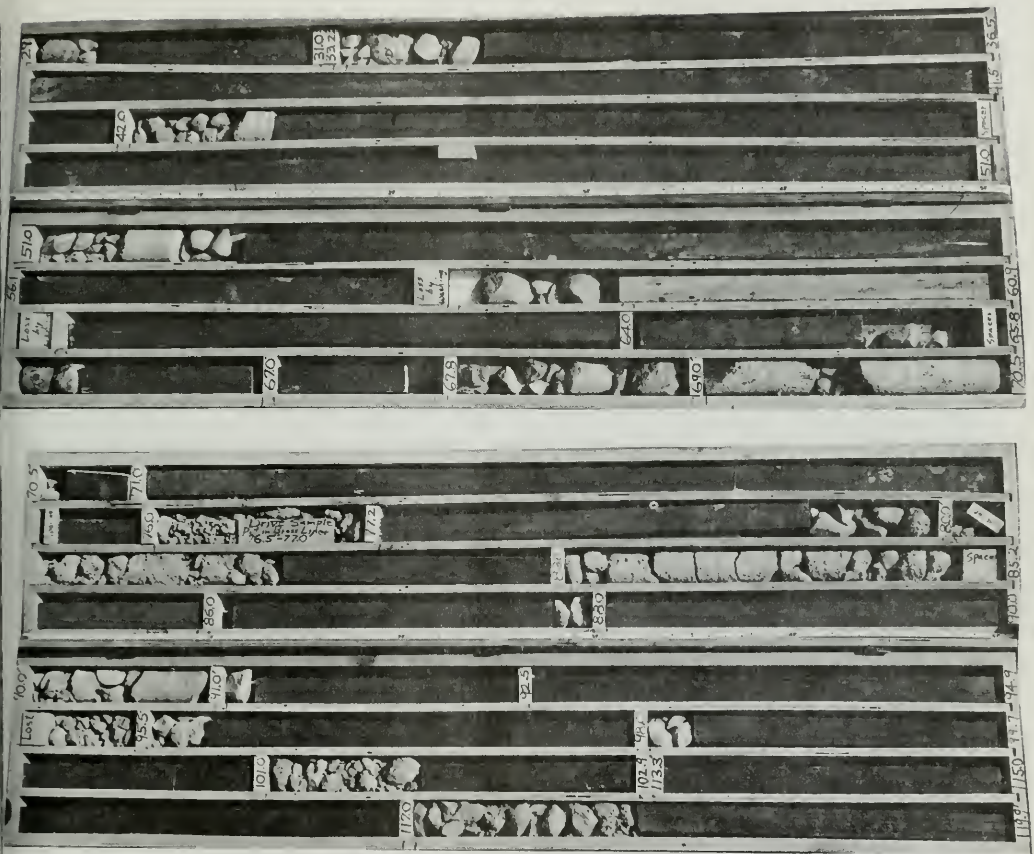
SYSTEM 1 AND 2, STATION A PUMPING PLANT,
DRILL HOLE PP-1, 18.0' TO 124.7'.

C-1

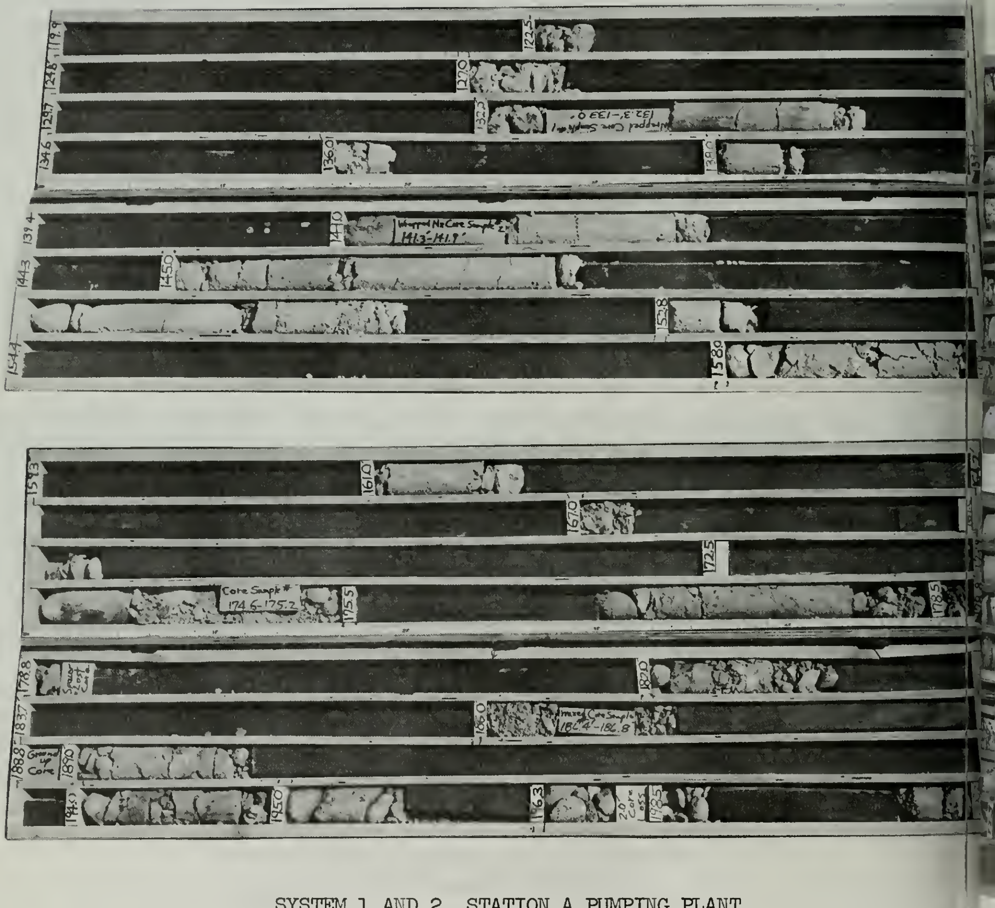




SYSTEM 1 AND 2, STATION A PUMPING PLANT,
DRILL HOLE PP-2, 29.0' TO 109.3'.

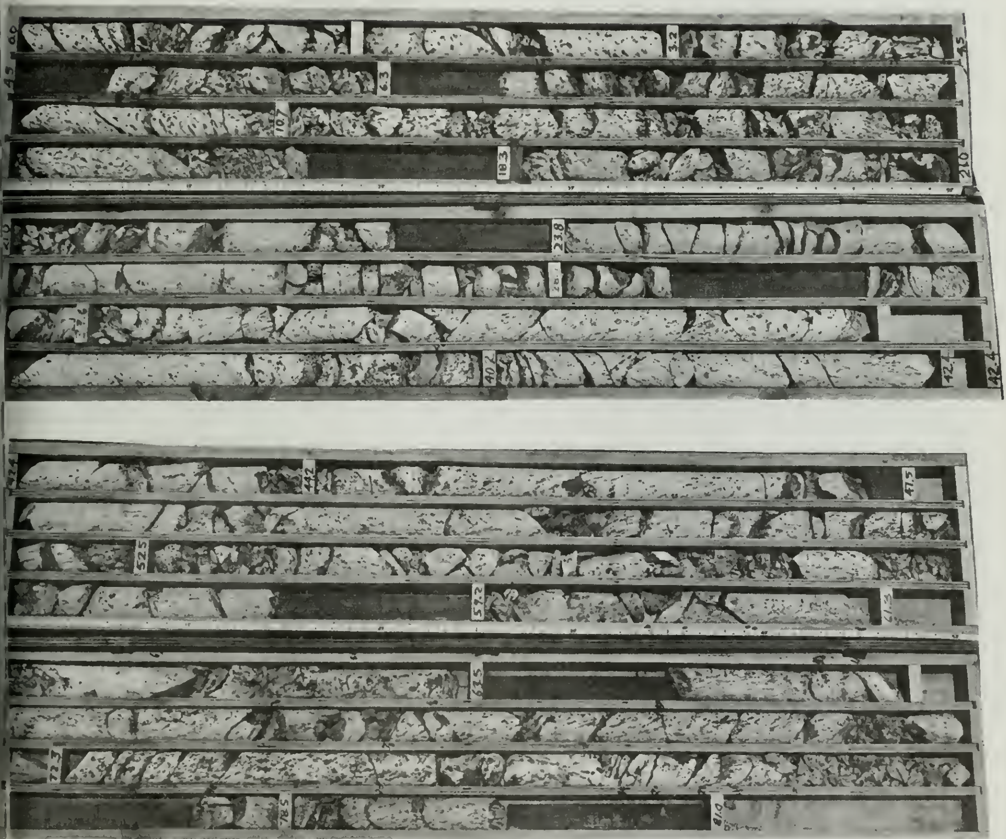


SYSTEM 1 AND 2, STATION A PUMPING PLANT,
<u>DRILL HOLE PP-3</u>, 29.5' TO 119.9'.
(CONTINUED)

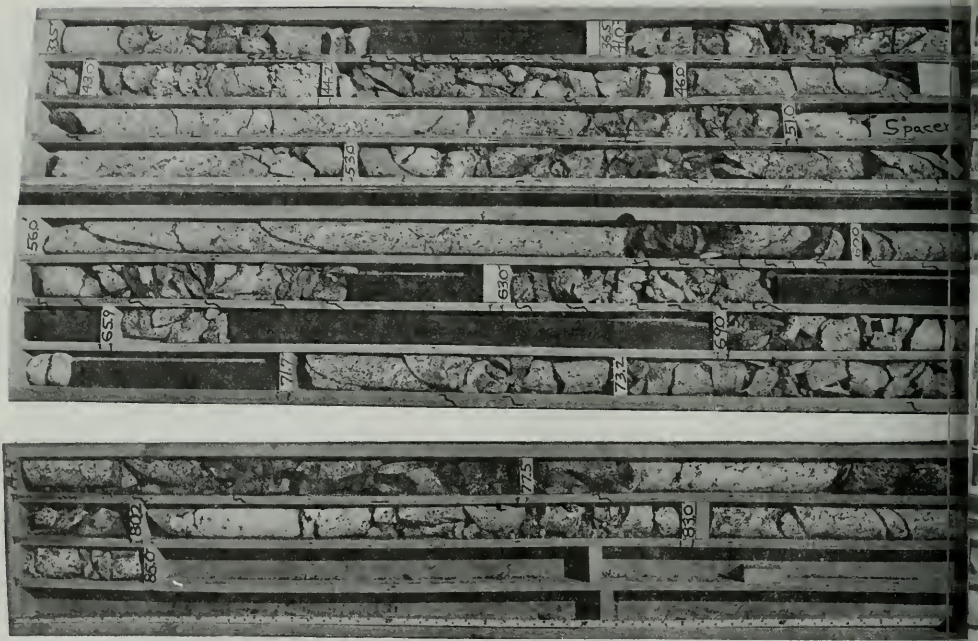


SYSTEM 1 AND 2, STATION A PUMPING PLANT,
DRILL HOLE PP-3, 119.9' TO 200.2'.

C-4



SYSTEM 1, EQUAL LIFT DAMSITE -
BASE OF RIGHT ABUTMENT,
DRILL HOLE DDH-1, 0.0' TO 81.0'.

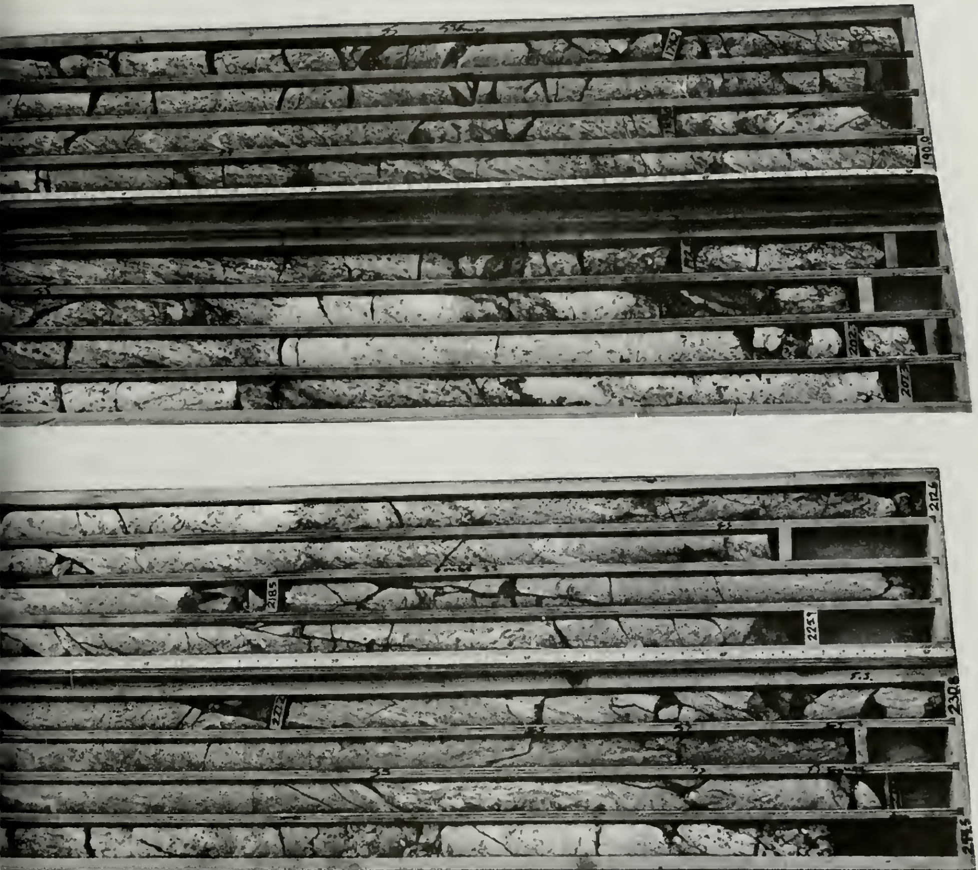


SYSTEM 1, EQUAL LIFT DAMSITE -
CHANNEL, DRILL HOLE DDH-6, 33.5' TO 85.0'.

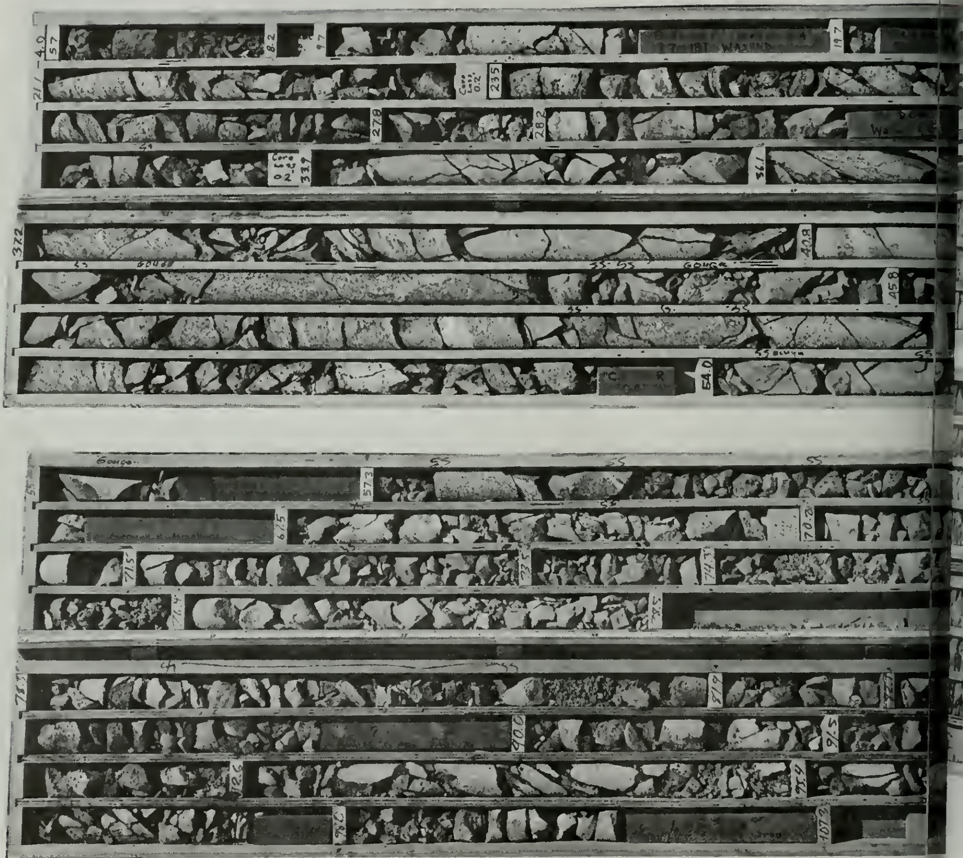
SYSTEM 1, EQUAL LIFT DAMSITE -
LEFT CHANNEL, DRILL HOLE DDH-4, 8.0' TO 98.3'.
(CONTINUED)

C-7

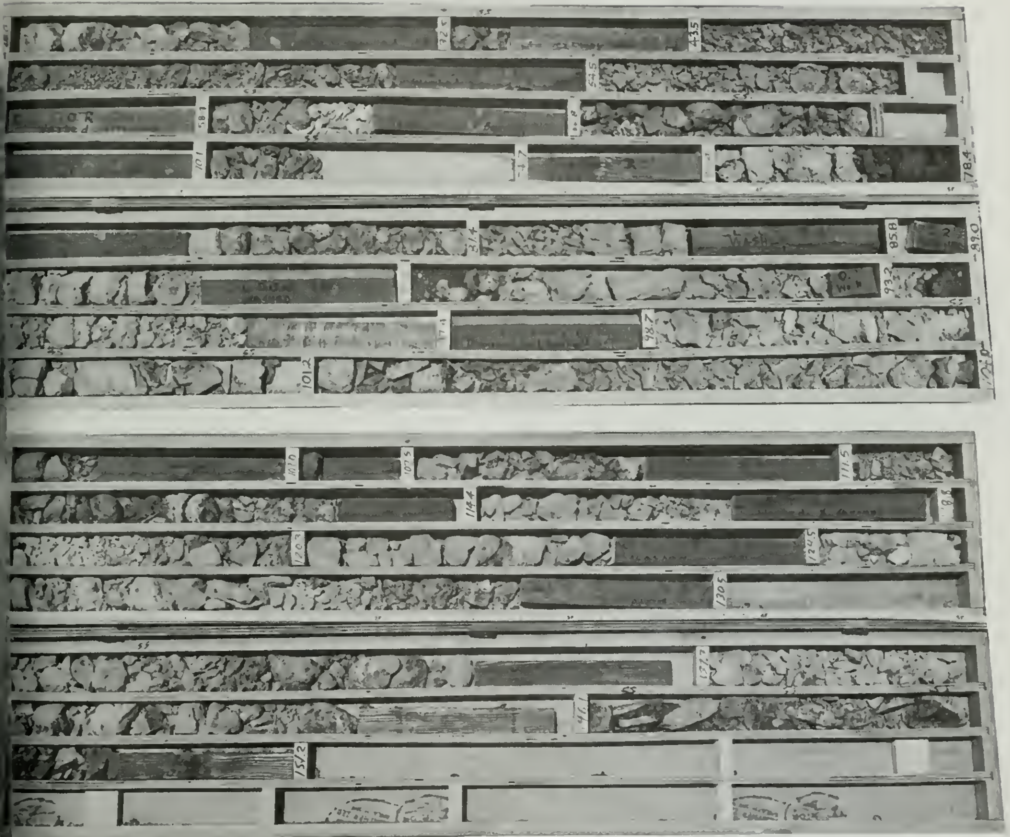
SYSTEM 1, EQUAL LIFT DAMSITE -
LEFT CHANNEL, DRILL HOLE DDH-4, 98.3' TO 170.7'.
(CONTINUED)



SYSTEM 1, EQUAL LIFT DAMSITE -
LEFT CHANNEL, DRILL HOLE DDH-4, 170.7' TO 244.5'.

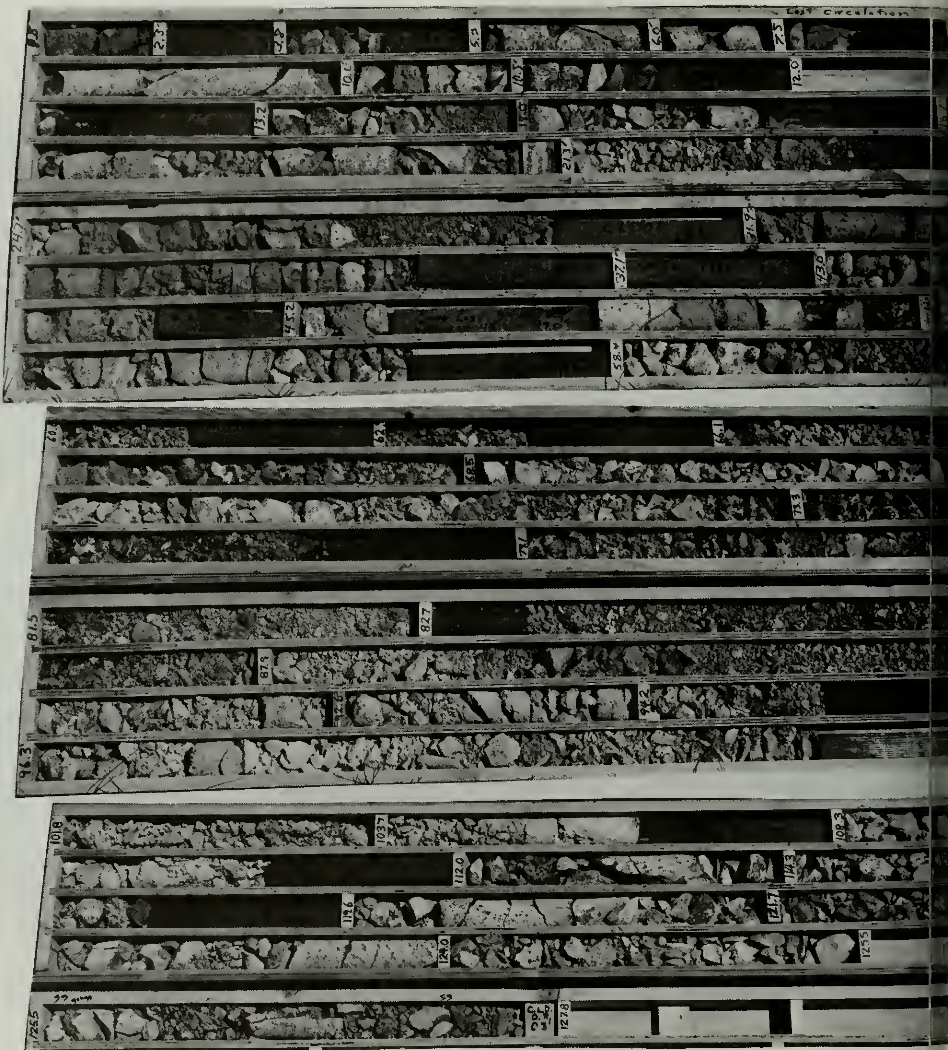


SYSTEM 1, EQUAL LIFT DAMSITE -
LEFT ABUTMENT, DRILL HOLE DDH-5, 4.0' TO 107.3'.



SYSTEM 1, EQUAL LIFT DAMSITE -
LEFT ABUTMENT AND ALTERNATIVE SPILLWAY,
DRILL HOLE DDH-2, 20.0' TO 151.2'.

C-11



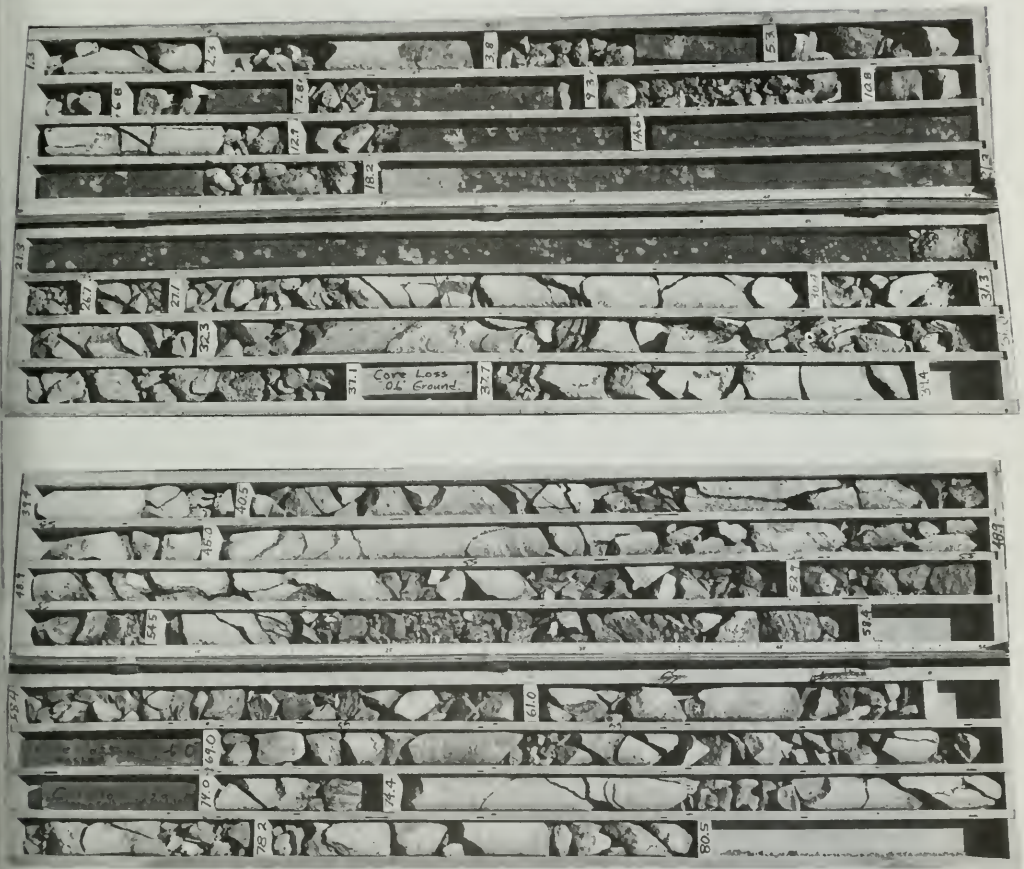
SYSTEM 1, STATION B PUMPING PLANT,
DRILL HOLE DDH-8, 1.8' TO 127.8',
HOLE WAS DRILLED TO TOTAL DEPTH OF 180 FEET.

C-12

SYSTEM 2 AND 3, UNEQUAL LIFT DAMSITE,
RIGHT ABUTMENT, DRILL HOLE DDH-7, 7.7' TO 85.9',
HOLE WAS DRILLED TO TOTAL DEPTH OF 98 FEET.

SYSTEM 2 AND 3, UNEQUAL LIFT DAMSITE,
CHANNEL, DRILL HOLE DDH-9, 15.5' TO 53 + FEET,
HOLE WAS DRILLED TO TOTAL DEPTH OF 75.5 FEET.

C-14



SYSTEM 2 AND 3, UNEQUAL LIFT DAMSITE,
LEFT ABUTMENT, DRILL HOLE DDH-3, 1.3' TO 80.5'.

C-15

SYSTEM 4, OFF-LINE DAMSITE,
RIGHT ABUTMENT, DRILL HOLE DH-88, 6.0' TO 109.8'.

APPENDIX D

The Consulting Board for Earthquake Analysis was convened on April 6, 1965, for the purpose of reviewing the engineering and geologic studies which were in progress. A copy of the report of the Board is given in this appendix.

COPY COPY

Los Angeles, California
April 8, 1965

Mr. Alfred R. Golze', Chief Engineer
Department of Water Resources
Post Office Box 388
Sacramento, California

Subject: Tehachapi Crossing

Dear Mr. Golze':

This letter summarizes our opinions formed as the result of work carried out on April 6 and 7, 1965, in connection with the evaluation of the relative seismic hazards of the various possible alignments of the Tehachapi Crossing.

On April 6, our Board was given a briefing by your staff on the engineering and geological studies which have been carried out to date, and then we were taken on an inspection tour of the whole area. On April 7, we had another joint meeting with your staff and finally spent several hours in closed session discussing the problem and forming the opinions described below. Messrs. Leps and Marliave of your Tehachapi Crossing Consulting Board joined us in all the discussions and the field trip.

In your letter of April 1, 1965, you asked:

> "Considering the several schemes proposed for an aqueduct crossing the Tehachapi Mountains from the standpoint of earthquake hazard, which of these would:
>
> "(a) Be the most reliable.
> (b) Be the least vulnerable to damage.
> (c) Be the most vulnerable to damage.
> (d) Present minimum hazard to life and property.
>
> "Please discuss any factors which in your opinion significantly affect the reliability or safety of each of the schemes, again from the point of view of earthquake related hazards."

1. We feel that there is insufficient information available to us at the present time to justify specific differentiation between the several schemes on the basis of earthquake hazard. Thus, we limit our main considerations to the two basic plans for effecting the Tehachapi Crossing -- the Pastoria Canyon scheme and the Ridge scheme.

In our opinion, the information does not warrant any more specific statements than those presented in our report of December 22, 1964, except to the extent that the information obtained in the intervening months and the observations made during our visit to the site reinforce the views previously presented. For example, we feel that the damsites in the Canyon scheme and the danger of instability of natural slopes during earthquakes are worse than we had previously assumed. In this connection, we note again that the hazards resulting from earthquake-induced landslides are greater for the Canyon scheme than for the Ridge scheme.

Thus, we find no reason to modify the conclusion expressed in our report of December 22; that is, while the crossing can be effected by either scheme the Ridge scheme is preferable to the Canyon scheme in that it is less vulnerable to damage and presents less potential hazard to life and property

Furthermore, in connection with the Ridge scheme, we prefer the use of tunnels in sound rock to surface installations in weathered material on steep slopes.

2. We note certain undesirable features of both schemes which merit further study:

(1) The siphon between Tunnels Nos. 2 and 3 on the Ridge alignment appears to be very vulnerable to loss of foundation support due to ground failure or by landslides induced by earthquakes.

(2) The abutment conditions for the damsites so far explored in the Canyon scheme are relatively poor and our inspection of the samples recovered from the drill hole in the left abutment of Damsite No. 1 revealed the presence of a thin layer of cohesionless material which may be susceptible to marked loss of strength during an earthquake. For planning purposes, we consider it more desirable to devote any further effort to studies of other possible damsites along the Canyon route rather than to more detailed study of those already investigated.

(3) The use of small reservoirs in this area, where there is such a large danger of landslides during earthquakes, introduces severe hazards from the following points of view:

(a) A small reservoir may be largely filled by an earthquake-induced landslide.

(b) Such a slide may cause overtopping of dams, and,

(c) Slide debris may damage the pumping system.

3. Of the various schemes proposed, we feel that System No. 1 involving conveyance of water in a closed conduit for a length of about a mile along the Garlock fault is the scheme most vulnerable to damage from the point of view of earthquake hazards.

4. We note that some consideration is being given to location of a dam and reservoir in the vicinity of the Garlock fault or the North Garlock fault and point out that any offset occurring along these faults would be more hazardous to a dam than to tunnels across the faults.

5. We would like to reiterate a statement from one of our previous reports that the overall reliability of any scheme will often depend more on the detailed treatment of the engineering problems involved than on the inherent hazards of any single general alignment.

Respectfully submitted,

/s/ ______________________
Dr. Hugo Benioff, Chairman

/s/ ______________________
Dr. Clarence R. Allen

/s/ ______________________
Dr. George W. Housner

/s/ ______________________
Dr. H. Bolton Seed

/s/ ______________________
Dr. James L. Sherard

/s/ ______________________
Mr. N. D. Whitman, Jr.

Memorandum from A. R. Golze' to J. J. Doody, January 15, 1965

Memorandum from J. J. Doody to J. M. Haley and A. R. Golze', January 29, 1965

Memorandum from D. P. Thayer to H. G. Dewey, Jr. and A. R. Golze',
February 10, 1965

Letter Report from Consulting Board for Earthquake Analysis to
A. R. Golze', April 8, 1965

Memorandum from A. R. Golze' to W. E. Warne, April 23, 1965

Memorandum from D. P. Thayer to A. R. Golze' and W. E. Warne,
April 28, 1965

Letter Report from Tehachapi Crossing Consulting Board to A. R. Golze',
May 8, 1965

Mr. J. J. Doody

Tehachapi Crossing

Alfred R. Golze'
Chief Engineer

Confirming the discussion in your office on January 13, it is understood the following action will be taken with respect to finalizing the information required for decision on the lift at the Tehachapis.

a. The target date for the report from your office is April 29, 1965.

b. Six systems will be included in the report. They are:

1. The Bechtel alignment on Pastoria Creek for a two-lift system modified to eliminate the upper reservoir on Garlock fault.

2. DWR two-lift system on Pastoria Creek.

3. DWR two-lift system on the Ridge Route.

4. DWR two-lift system of a combination of the Ridge Route and Pastoria Creek.

5. DWR single lift on the Ridge Route with surface penstocks.

6. DWR single lift with underground penstocks.

c. A Q of 4,000 cfs will be used in the final report. Mr. Wilkes will confer with Mr. Thayer to obtain the necessary engineering assistance to work out the changes in data.

d. Photographs should be taken of all the proposed locations for pumping plants, dams, reservoirs, etc. It might also be well to have a large aerial photograph of the pumping area and the routes plotted on the aerial photograph rather than on a conventional contour map. Photographs should be included in the report and enlargements should also be available for display purposes.

e. Presentation to the Director will be scheduled about mid-May advising him of the engineering decision on the pumping lift part of the Tehachapi Crossing.

cc: Mr. H. G. Dewey, Jr.

ARGOLZE:mgb

State of California

The Resources Agency

Files

Memorandum

To : 1. Mr. J. M. Haley
2. ~~Mr. A. R. Golze'~~

Date : January 29, 1965

File No.:

Subject : Tehachapi Crossing

James J. Doody
District Engineer
Southern District

From : Department of Water Resources

633.10
CA Tehachapi

Reference is made to the subject memorandum dated January 15, 1965, in which Mr. Golze' set forth the boundary conditions under which we are re-investigating Tehachapi pumping lifts up the Ridge Route and, alternatively, up Pastoria Creek. This will confirm that we are studying the Tehachapi pumping lift alternatives within these boundary conditions. Additionally, in our minutes of the meeting with the Chief Engineer on Wednesday, January 13, 1965, we noted the following boundary conditions:

1. Power rates will be the latest available. In this connection, the Power Office has been contacted for power rates and has advised us of its recommendation.

2. The latest estimates for efficiencies of pumping machinery will be used.

3. The study will consider all points raised by the Bechtel Corporation in its reports to MWD.

4. Our report on this study will be transmitted to Mr. Golze' on or before April 29, 1965.

We wish to bring to your attention that Mr. Glen Smith of MWD, who is designated by that organization to effect liaison with the Department has, several times during the past week, emphasized that both the Bechtel Corporation and MWD are extremely interested in a three-lift pumping scheme up Pastoria Creek. We would appreciate your instructions as to whether a seventh alternative system should be included in our study and report. This seventh would be a three-lift pumping scheme up Pastoria Creek. Since, in our past investigations, we have considered three-lift schemes, the incorporation of this alternative in the studies would require merely the updating and refining of data already available.

Attached herewith are notes taken on the Chief Engineer's meeting with the staff of the Design and Construction Branch of the Southern District on Wednesday, January 13, 1965. The part of the meeting on the Tehachapi Crossing is covered on pages 3 and 4.

See my memo of 2/10/65 to
A.R. Golze' ~~the~~ same subject
Haley

FEB 1 1965

SURNAME

(REV. 4-62)

Doody

It is proposed that this reinvestigation of the Tehachapi lift be accomplished by engineers and geologists currently engaged in design work on other Southern District programs. The programs involved are:

1. Cottonwood Powerplant Site Development Design
2. Oso Pumping Plant Site Development Design
3. Perris Reservoir Preliminary Design
4. San Bernardino Tunnel and Intake

At this time, it appears that there will be no measurable effect on the schedules for design of Cottonwood and Oso Plant site development. There will, of course, be a reduction in manpower available on these programs and, accordingly, a reduction in the degree of refinement in the early phases of the work; this is not expected to restrict the scheduled completion.

The work necessary for the exploration and study of dams in Pastoria Creek on the Tehachapi lift reinvestigation will result in a reduction of effort on the preliminary design and exploration for Perris Dam and Reservoir and for the San Bernardino Tunnel, which will necessitate approximately two months' delay in the completion of preliminary design on these programs.

Accordingly, your approval is requested for a two-month delay in the completion of preliminary design and start of final design on Perris Dam and Reservoir (which it is assumed can be absorbed in the scheduled time for final design), and a two-month delay in the total program for the San Bernardino Tunnel (which will not affect water delivery).

APPROVED: subject to concurrent approval of Thayer memo to AKB

Alfred R. Golze'
Chief Engineer

Date Feb 10, 1965

Attach./
cc: Chief Engineer's Office
Southern District Office
Mr. H. G. Dewey, Jr.
Attention: Mr. E. W. Stroppini
Mr. J. W. Keysor
Attention: Mr. J. W. Marlette
Mr. D. H. McKillop
Mr. P. E. Hood
Mr. J. A. Purvis
Attention: Mr. A. B. Arnold
Mr. R. D. Gilstrap
Mr. H. Markosian
Mr. A. Hunter

1. Mr. H. G. Dewey, Jr.
2. Mr. Alfred R. Golze'

February 10, 1965

Tehachapi Crossing

Donald P. Thayer

Reference is made to memorandum to Mr. Golze' from Mr. J. J. Doody, dated January 29, 1965, same subject, suggesting inclusion of the three-lift Tehachapi Pumping Scheme on a route through Pastoria Canyon in our current studies of alternatives for the subject part of the project. You orally requested me on February 5, 1965, to review and report to you on this memorandum.

I have conferred with personnel of the Southern District office and find that no new conditions have arisen motivating this suggestion other than those presented to you in forming the basis of your previous decision to study six different schemes for the Tehachapi Crossing. On January 25, 1965, just prior to my trip to the Southern District on the following day, I called your attention to the fact that our proposed investigation did not include the three-lift scheme. At that time you confirmed your instructions as to the six schemes to be studied.

Our preliminary estimates of cost of the various alternative schemes for the Tehachapi Crossing showed the three-lift scheme via Pastoria Canyon to be more costly than the most economical alternative. The preliminary report to MWD by the Bechtel Corporation dated September 1964, estimated the three-lift scheme would cost $17,000,000 more than the least

costly alternative. The Bechtel letter report to MWD of January 5, 1965, indicated that the three-lift scheme via Pastoria Canyon to be $14,000,000 more costly than the most economical alternative.

Preparing alternative studies of the six schemes which you have already approved within the time indicated will already tax the resources available to the uttermost; adding another schee to this study will result in delaying other essential work.

I have previously informed you in my memorandum of January 29, 1965, reporting on the presentation made by the Bechtl Corporation before the MWD Board of Directors on January 26, 1965 that sentiment among the directors seemed to be strong for the use of single stage pumps. For reasons which I have outlined to you heretofore, it is, however, only practicable to use single stage pumps in connection with the three-lift system. I do not believe this to be a valid reason for further study of a system already demonstrably uneconomical and needlessly complicated.

For the above reasons, on strictly technical engineerin considerations, I recommend that you make no change in your forme instructions to study six alternatives for the Tehachapi Lift.

DPThayer:cp

APPROVED:

Alfred R. Golzé

Chief Engineer

Date FEB 17 1965

Los Angeles, California
April 8, 1965

Mr. Alfred R. Golze', Chief Engineer
Department of Water Resources
Post Office Box 388
Sacramento, California

Subject: Tehachapi Crossing

Dear Mr. Golze':

This letter summarizes our opinions formed as the result of work carried out on April 6 and 7, 1965, in connection with the evaluation of the relative seismic hazards of the various possible alignments of the Tehachapi Crossing.

On April 6, our Board was given a briefing by your staff on the engineering and geological studies which have been carried out to date, and then we were taken on an inspection tour of the whole area. On April 7, we had another joint meeting with your staff and finally spent several hours in closed session discussing the problem and forming the opinions described below. Messrs. Leps and Marliave of your Tehachapi Crossing Consulting Board joined us in all the discussions and the field trip.

In your letter of April 1, 1965, you asked:

"Considering the several schemes proposed for an aqueduct crossing the Tehachapi Mountains from the standpoint of earthquake hazard, which of these would:

"(a) Be the most reliable.
(b) Be the least vulnerable to damage.
(c) Be the most vulnerable to damage.
(d) Present minimum hazard to life and property.

"Please discuss any factors which in your opinion significantly affect the reliability or safety of each of the schemes, again from the point of view of earthquake related hazards."

1. We feel that there is insufficient information available to us at the present time to justify specific differentiation between the several schemes on the basis of earthquake hazard. Thus, we limit our main considerations to the two basic plans for effecting the Tehachapi Crossing -- the Pastoria Canyon scheme and the Ridge scheme.

In our opinion, the information does not warrant any more specific statements than those presented in our report of December 22, 1964, except to the extent that the information obtained in the intervening months and the observations made during our visit to the site reinforce the views previously presented. For example, we feel that the damsites in the Canyon scheme and the danger of instability of natural slopes during earthquakes are worse than we had previously assumed. In this connection, we note again that the hazards resulting from earthquake-induced landslides are greater for the Canyon scheme than for the Ridge scheme.

Thus, we find no reason to modify the conclusion expressed in our report of December 22; that is, while the crossing can be effected by either scheme the Ridge scheme is preferable to the Canyon scheme in that it is less vulnerable to damage and presents less potential hazard to life and property.

Furthermore, in connection with the Ridge scheme, we prefer the use of tunnels in sound rock to surface installations in weathered material on steep slopes.

2. We note certain undesirable features of both schemes which merit further study:

(1) The siphon between Tunnels Nos. 2 and 3 on the Ridge alignment appears to be very vulnerable to loss of foundation support due to ground failure or by landslides induced by earthquakes.

(2) The abutment conditions for the damsites so far explored in the Canyon scheme are relatively poor and our inspection of the samples recovered from the drill hole in the left abutment of Damsite No. 1 revealed the presence of a thin layer of cohesionless material which may be susceptible to marked loss of strength during an earthquake. For planning purposes, we consider it more desirable to devote any further effort to studies of other possible damsites along the Canyon route rather than to more detailed study of those already investigated.

(3) The use of small reservoirs in this area, where there is such a large danger of landslides during earthquakes, introduces severe hazards from the following points of view:

(a) A small reservoir may be largely filled by an earthquake-induced landslide.

(b) Such a slide may cause overtopping of dams, and,

(c) Slide debris may damage the pumping system.

3. Of the various schemes proposed, we feel that System No. 1 involving conveyance of water in a closed conduit for a length of about a mile along the Garlock fault is the scheme most vulnerable to damage from the point of view of earthquake hazards.

4. We note that some consideration is being given to location of a dam and reservoir in the vicinity of the Garlock fault or the North Garlock fault and point out that any offset occurring along these faults would be more hazardous to a dam than to tunnels across the faults.

5. We would like to reiterate a statement from one of our previous reports that the overall reliability of any scheme will often depend more on the detailed treatment of the engineering problems involved than on the inherent hazards of any single general alignment.

Respectfully submitted,

Hugo Benioff

Dr. Hugo Benioff, Chairman

Clarence R. Allen

Dr. Clarence R. Allen

George W. Housner

Dr. George W. Housner

H. Bolton Seed

Dr. H. Bolton Seed

James L. Sherard

Dr. James L. Sherard

N. D. Whitman

Mr. N. D. Whitman, Jr.

Mr. William E. Warne

Alfred R. Golze'
Chief Engineer

Tehachapi Crossing,
European Trip,
April 3-16, inclusive

On April 3, I departed for Zurich, Switzerland, accompanied by Don Thayer of the Department, David Miller and Hans Gartmann of DMJM, Robert Skinner, Chief Engineer and General Manager of MWD and Myron McBride, Director of MWD. For parts of the trip in Europe we were accompanied by Paul Winn and W. Rockwell of MWD engineering staff. Otto Hartman of Motor-Columbus accompanied us in Europe the first week of the trip.

The purpose of the trip was to examine the work being done in Europe for the Department as part of the pump program for the Tehachapi Crossing. We inspected the pump models at two of the European manufacturing plants, conferred with engineers of the plants and others associated with the design and manufacture of high-head pumps, inspected high-head pump plants in operation, conferring with operating personnel, and visited the National Engineering Laboratory of Great Britain at Glasgow for a briefing on the Bechtel-MWD pump model test program.

The initial meeting of the group was held in Zurich on Sunday evening, April 4, at which time the plans for the trip were discussed and agreement reached on details. Also at this Sunday meeting Hans Gartmann gave a report on the meeting of the Technical Advisory Board of DMJM that was held during the previous week. The

Board found that the three types of pumps under study were all satisfactory for the Tehachapi Crossing in an appropriate lift arrangement. The Board found the two-stage double flow pump for the two lift scheme the best machine for that lift.

On Monday, April 4 we went to the plant of the Sulzer Brothers at Winterthur, Switzerland. This is an old company going back to 1834 and they have made a number of multi-stage pumps and pipelines for high-head lifts. They do not do the electrical work which is contracted separately to electric companies such as Brown Boveri. Sulzer showed slides of pumps and pipelines that they had built and a film of the plant in Wales called Ffestiniog for which Sulzer built all the pumps and two of the four penstocks. This plant uses two-stage double-flow pumps very similar to that which would be used for the Tehachapi Crossing on a two-lift basis. Sulzer explained the details of the model that they were testing for the Department of Water Resources which is a four-stage single flow pump. This model test so far had not developed as high an efficiency as expected. Additional work on the model will be done to improve the efficiency such as changing guide vanes, introducin tighter seal clearances and redesigning the labyrith seal.

In the discussion at Sulzer it was brought out that the four-stage pump proposed for the Tehachapis has not been used in prototype in Europe although higher heads have been handled very well by five stage pumps of similar design. The Sulzer engineers stated, however, there would not be any major problem in handling or designing the four stage pump designed for the Tehachapi Crossig

The Sulzer engineers suggested the specific speed of the Tehachapi pump could be reduced for the single lift which in turn would require five stages instead of four. It was also brought out that quality of water used in the pumps has an influence on pump performance, largely through wear of the impellers. The models in Europe are being tested on good quality water so that wear is not considered, but at the Tehachapi water quality is important. Separately, the Department (through DMJM) is running a wear test at the Tracy pumping plant of the Bureau of Reclamation.

The general picture obtained from the visit to the Sulzer plant was that the four-stage single lift pump model being tested for the Department showed that such a pump could be built and that it would operate satisfactorily, but that consideration possibly should be given to a five stage pump as an alternative if the single lift is selected for the Crossing.

On April 6, the group went to Baden, Switzerland for a visit to the office of Motor-Columbus. Motor-Columbus is a subcontractor for the Department under the DMJM contract. They advise the Department on high-head pumps and represent the Department in our European model testing work. Motor-Columbus is an older organization made up by the combination of two separate firms: (1) the Motor Company being a promotor of development of electrical energy in Switzerland, and (2) Columbus a financial organization supporting power development schemes in Latin America. The two were combined in the 1920's to form the organization known as Motor-Columbus which today is an engineering organization engaged primarily in making

feasibility studies for various states, governments, private companies and utilities around the world. They have worked in practically all important countries except the United States. In addition to preparing feasibility reports, Motor-Columbus prepares specifications and supervises construction of projects, but does not actually do the construction work.

Motor-Columbus reported on its considerable experience with the engineering of high-head pumping and power plants. They have had considerable work on underground plants and penstocks. It was noted that they follow a design procedure very similar to that being used in the Department of Water Resources. Motor-Columbus engineers outlined in some detail for the benefit of our engineers the design factors considered in construction of penstocks such as the use of new high-strain steel, and improved methods of grouting penstock liners. Motor-Columbus was active in the design of the first pump-storage plants built in Switzerland 30 years ago and have pioneered in the design of equipment for work exceeding the then current experience.

On April 7, the group visited the offices of the J. M. Voith Company in Heidenheim, Germany. It is another old European company, manufacturing heavy machinery and equipment. A briefing was held with the engineers of this company who reported on their extensive experience in designing and manufacturing heavy duty hydro-generating equipment. This company has been active in the United States going back before World War I and has worked around the world. They are presently constructing machinery for the American River Power Plants of SMUD.

For the Department of Water Resources Voith has made a model of a two-stage double-flow pump that would be used in a two-lift scheme crossing the Tehachapis. The model test so far have indicated an unexpectedly good efficiency well above 90 percent. In a general discussion of both the model and high-head pumps the Voith engineers stated they generally followed a rule of about 200 meters per stage of pump. For a 1000 foot lift, they find that the two-stage double-flow pump would offer the greatest reliability and freedom from abraison.

The Department's model was witnessed in operation at a slow speed; the high-speed tests were scheduled to follow. The entire setup was very business like and efficient in appearance. In answer to questions from MWD representatives present as to whether a single stage pump could be designed for a 900-foot head, the Voith engineers said that such a pump could be designed but that it was beyond current experience and the quality of water would have an influence on the performance. In answer to a direct question as to what is the best type of pump for a 1,000 foot head for average water, the Voith engineers answered that the two-stage double-flow pump would be their choice.

On April 8, a visit was made to the Lunersee plant in the Austria Alps. The Lunersee plant has five five-stage pumps with a lift of 3,150 feet (50% greater than the Tehachapi lift). The pumps were not operating during our visit as the plant was operating on-peak. In a discussion with the Deputy Plant Superintendent, Mr. Kuhn, he advised that the pump units were inspected and checked out each year, taking one or two weeks each

to do this. The equipment is not dismantled. The pumps at this plant consist of two made by Voith, one by Sulzer and two by Escher-Wyss (another manufacturer of high-head hydro equipment). The Voith pumps have had no cavitation, the Sulzer pump had a little cavitation, but the Escher-Wyss pump has had sufficient cavitation to require repair work.

In seven years of operation at Lunersee there had been no unscheduled outage of the pumps in more than 15,000 hours of operation. The pumps are started and stopped an average of 1,000 times a year, but because the generator-motors are always spinning as a reserve on the central Europe network, it does not directly compare with the Tehachapi off-peak situation where both the pump and motors would have to be started daily from rest. Considering all three makes of pumps at Lunersee, the superintendent stated the Voith pumps are giving the overall best performance although the other two are quite satisfactory.

After leaving the Lunersee plant we went to the nearby Rodund Plant which was also in Austria. This plant has only one pump which is a horizontal double-flow two-stage pump made by the Voith Company. It pumps up a head of 348 meters (1,142 feet). The pump was not operating during our visit. The superintendent, a Mr. T. Laeugei, advised that there had been no problems with the pump, and it had operated satisfactorily.

On April 9, we went to Tierfehd, Switzerland, to the Linth-Limmern Plant. This is an underground plant with five generators and two separate pumps. These pumps work against a head of 559 meters, the pumps are started on 60 percent voltage full of

water. They are classed as three-stage single flow pumps. One of the pumps was started up during our visit. It operated very smoothly and very quietly. The capacity of each pump was about 140 cfs.

Also, on April 9, we visited the Etzel Plant near Zurich in Switzerland, where there are two five-stage single flow units. These are vertical pumps connected to a motor that is also used separately as a generator. The motor and pump are connected by a friction clutch. The pumps are operating against a head of 475.8 meters. This plant has been in operation since 1946 and the pumps have not been dismantled since their installation. Because of sufficient submergence there had been no cavitation. Also, with the good quality of water available and the relatively slow speed (500 RPM) there had been little erosion. These pumps were made by Sulzer Brothers of Switzerland. One of the pumps was started and stopped during our visit. It was a noisy operation.

Back in Zurich on the evening of April 9, a meeting of the entire group was held to summarize the week's activity. I expressed the view that it was apparent from our discussions with the Sulzer and Voith engineers and our visits to the plants that a good pump could be found for any of the six schemes under study by the Department. Mr. Skinner stated that he generally agreed and he expressed the view that the two-stage double-flow pump, on the basis of the information made available to us, has a few points over other pumps. He also recognized that civil engineering factors would probably control the decision on the lift to be used at the Tehachapi. Myron McBride of MWD concurred with Mr. Skinner's view. At this meeting there was considerable discussion of details on such matters

as the questions as to whether the pumps should be vertical or horizontal, how much weight should be given to specific speed, and supplemental questions such as surge tanks, starting the pumps dry or filled with water, the proper design of the electric motors, leakage at seals, labyrith design, etc.

On April 12, we were in Luxenburg for a visit to the new Vianden plant. This plant, 40 miles north of the City of Luxenburg, is connected to and operates as part of the central Europe inner-connected system (10,000 megawatts) and is controlled from Coblenz. A Mr. Kass was the superintendent in charge.

The Viaden plant has nine pump units of the two-stage double-flow type similar to that being tested for the two lift Tehachapi Crossing. These pumps operate against a head of 268 to 29 meters. During the time of our visit seven units were operating as generators. The first unit started in October 1962 and the last in October 1964. Its pump number 2 has operated 6200 hours which is considered a maximum under the type of operation at Vianden. The pumps customarily operate between 12 midnight and 6 a.m. pumping water to an upper basin. The water returns from the upper basin through separate generators for the generation of power during peak periods. The pumps were made by Escher-Wyss of Germany, Voith of Germany, and by one of the French companies. The pumps have been installed in a horizontal position which has apparently caused no problems such as shaft distortion. The plant is an underground one and in appearance is similar to the Oroville generation machine hall

There have been no operating problems of consequence at Vianden other than some work that is presently being done on its

Number 1 unit, where trouble had been encountered due to a loose guide vanes. Its number 4 unit was shut down for its annual general maintenance which is done by inspection made through manholes. We were given the opportunity of examining this maintenance work then in progress.

The group had originally been invited to go to Ffestiniog in Wales which is another plant of the two-stage double-flow type similar to those proposed for the two-lift system on the Tehachapis. We were not able to go because of conflicts with other visitors at the plant, so instead the group went to London and on April 14 paid a visit to the office of Kennedy and Duncan, Consulting Engineers. There we were able to talk with Mr. Headland, who was the design engineer for the Ffestiniog plant.

In discussions with Mr. Headland, he advised that the pumps were installed in a vertical position rather than horizontal (as seen in plants in Europe) in order to reduce the length of the building and to give a better setting of the turbines which are imbedded in concrete. The pump lift here is 1,000 feet or 500 feet per stage which he considers to be a conservative ratio. The pumps discharge 750 cfs and they do not have any water quality problem.

Manufacturing of the Ffestiniog equipment was done on a competitive basis and the award for the equipment was given to the English Electric Company with a sub-contract to Sulzer Brothers in Switzerland. English Electric was responsible for the installation and performance. Most of the equipment was manufactured in England under Sulzer designs. The model tests were made by Sulzer and showed

an efficiency of 90.3 percent. They have not made any acceptance tests in the field on the individual units but have checked the plant for overall efficiency, which is satisfactory to them.

The first unit has been in service since the end of 1961 and the last from the end of 1962. There has been some slight cavitation on the first stage impellers due to imperfections of blade finish. Aside from the work done for the Ffestiniog Plant, Kennedy and Duncan do general engineering work in the field of high-head construction plants. They are particularly well equipped to follow progress and to do inspection work at plants in Europe. It would appear that if the Department should eventually contract for overseas manufacturing of hydro or electrical equipment that Kennedy and Duncan might be a good representative to do the necessary inspections. They will furnish brochure material on their inspection services.

In commenting on the Ffestiniog Plant, Mr. Headland said that if he had it to do over again there would be very little that would be changed. He is convinced that the two-stage double-flow plant is undoubtedly the best design for this particular station with a lift and water quantity as dictated by the site selection.

On April 15 the group met at the National Engineering Laboratories at East Kilbride, Scotland. Here the group was a guest of The Metropolitan Water District and the Bechtel Corp. Bechtel had arranged a program of model testing of assorted pumps at the NEL. The models were collected from both Europe and America wherever available and were those made originally for pumps designed

some years ago and in no way were directly related to the Tehachapi Crossing requirements. The intended benefit of the Bechtel program was to find out the relationship between specific speeds for different types of pumps and to get some idea of quality comparisons between the different manufacturers.

Dr. Spencer who was in charge of the program at the laboratory explained the work in some detail and reported on the progress made to date. As far as the State Water Project is concerned, the principal items of interest related to the finishing or polishing of models as related to the type of finish obtained on prototypes. The question of specific speeds, and their importance to model and pump design again came up, and it is evident there is considerable difference of opinion among the technical experts,some holding that specific speeds are not very meaningful and others that they are a vital factor in pump design. It seemed to be agreed, however, that revolutions per minute (rpm) was a more realistic approach to a model performance than the specific speed which is an artificial number derived by formula.

The future program at NEL was discussed. They are going ahead with testing new models ordered by MWD of three different single-stage pumps to be used for a 1,000 foot head, which is well beyond any experience of this type of pump to date. There will not be any results of this test available in sufficient time to be useful to us at the Tehachapis. It was generally agreed by the professors and the engineers present that use of the single-stage for a two-lift at the Tehachapis is not practical at this stage

of pump development. However, Metropolitan wants their models tested for possible future use at plants other than the Tehachapis.

I have agreed to release to NEL at MWD's expense the Department's three models for further testing by NEL to get comparative data from one single laboratory. It is not expected that such testing would do much more than compare the capabilities of the three manufacturing plants. This testing of the DWR models at NEL will be done after the DMJM program is completed next fall.

An inspection of the National Engineering Laboratory indicated it to be one of the best equipped, if not the best equipped hydrology laboratory in the world. Its only limitation has been its capability to do high head turbine and pump testing. This is being overcome by the installation of a large heavy duty motor by MWD to provide the power needed for the handling of the large size models. At the time of our visit, the laboratory had under test a model furnished by the Byron-Jackson Company which turned out to be the model they used for the original pumps at Grand Coulee 15 years ago.

There was considerable cross-questioning between the visiting engineers and the laboratory staff on details of model manufacturing, step-up formulas, prototype finishing, specific speed, and relationship between efficiencies determined by NEL compared to efficiencies determined by the manufacturers.

The visit to the NEL concluded the trip of the group. A separate report will be submitted by Mr. Thayer which will cover the

technical details that were discussed at the different meetings and observed during the inspection of the various plants and facilities.

In general it was ascertained that there is no serious divergency of views between the engineers of the Department of Water Resources, DMJM, MWD, and the Bechtel Corp. relative to the performance of the pumps and their suitability for the different lifts being considered by the Department. It seems probable that the double-flow two-stage pump is best suited for the two-lift pumping lift and the four-stage pump will perform adequately for a single lift crossing of the Tehachapis. The four-stage might, however, be modified to a five-stage pump. The question of which pump to use will depend on the lift selection which will be influenced greatly by civil engineering matters.

The trip as a whole was profitable, not only in completing the experience background necessary to a full understanding of the pumping situation, but also as a means of securing a coordination of thinking among the various parties of interest with the hope that when the final decision is made it will be in general agreement with the conclusions of the various engineers and responsible officials concerned.

cc: Mr. H. G. Dewey, Jr.
Mr. D. P. Thayer

ARGOLZE:mgb

1. Mr. Alfred R. Golze'
2. Mr. William E. Warne

April 28, 1965

Tehachapi Crossing,
European Trip,
April 3-16, inclusive

Donald P. Thayer

Reference is made to Mr. Golze's memorandum to Mr. Warne of April 23, 1965, same subject.

There is attached my report on the subject trip. This is the report to which Mr. Golze' referred in the last paragraph on page 12 of his report referenced above.

Attachment

cc: H.G.Dewey,Jr.

INSPECTION TRIP IN EUROPE APRIL 5 TO APRIL 16, 1965

by Donald P. Thayer

This trip was made for the purpose of inspecting the pump research and development model testing subcontracts being conducted by the Sulzer Bros. Company of Winterthur, Switzerland, and the Voith Manufacturing Company of Heidenheim, Germany, under subcontract from Daniel, Mann, Johnson, and Mendenhall, who are conducting this study for the Department. At the same time, inspection was made of five high head pumping installations in Europe, which were considered particularly pertinent to the study of the Tehachapi Pumping Lift.

Those taking part in the inspection were as follows:

For the Department of Water Resources

Alfred R. Golze', Chief Engineer
Donald P. Thayer, Deputy Division Engineer, Design and Construction
T. W. Troost, Chief, Mechanical-Electrical Section
John Parmakian, Consultant

For Daniel, Mann, Johnson, and Mendenhall

David R. Miller, Vice President
Hans Gartmann, Project Engineer

For the Metropolitan Water District

R. A. Skinner, Chief Engineer and General Manager
Myron McBride, Director
W. Paul Winn, Senior Engineer
E. W. Rockwell, Chief Electrical Engineer

Certain of the above-mentioned individuals did not take part in certain inspections, as will be noted subsequently under the account of each inspection. Complete statistical data on the various pumping plants inspected are included in the Interim Report, "Investigation of High Head Pumping Practice in Europe, October 1964", by Daniel, Mann, Johnson, and Mendenhall.

Sulzer Bros. Plant, Winterthur, Germany

At this plant, we were greeted by Mr. George Sulzer, one of the partners and by the following officials who took part in the conferences:

Felix Von Wagner, Contract Manager
Rene' Strub, Vice Director
Mr. Florjancic, Chief Hydraulic Research Test Engineer
Mr. Canonica, Chief Engineer, Pumps
Mr. Rioult, Manager, Turbo Machinery
Mr. Duc, Project Engineer
Mr. Thomae, Test Engineer

The first part of the meeting in the company auditorium was devoted to a general orientation of the activities of the Sulzer Bros. Company. After this preliminary briefing we adjourned to the conference room, where the matter of the tests now under way was discussed. The meeting covered various design features associated with multi-stag pumps. The various components assembly and clearances were described by the Sulzer representatives and discussions were held on various types of pumps. In response to questioning, the Sulzer representative indicated that design of the multi-stage pump has been proven out by experience and would be the most conservative for the Tehachapi Crossing. They indicated also that they would model test single-stage pumps at 975 head and they believe that such pumps would be satisfactory. However, they could only base such predicted satisfactory performance on model testing alone as they had not built any single-stage pumps at this high head per stage. They mentioned their test work on the Cruachan Pump models but these machines have not been built or placed in operation yet. They indicated there would be more seal maintenance for the higher head per stage pumps and this would be dependent to a great extent on the amount of abrasive materia in the water.

They saw no problem in designing the water passages to accommodate the 313 cubic feet per second flow for the Tehachapi pump, and as far as specific speed is concerned, it was indicated that this could vary 5 percent up or down and our present model test work would still be applicable.

Sulzer has also started preliminary runs at the higher speeds of 2300 rpm. This corresponds to a prototype head of 1287 feet. The head capacity relationships were in accordance with the predicted values and the cavitation was lower than the predicted values. The cavitation break point occurs at approximately 48 feet impeller submergence which is lower than the predicted value of 55 feet used in our preliminary studies. At the time of the preliminary start-up runs, efficiencies of 87.7 percent had been obtained.

In connection with these runs, they had shaped the inlet surface of the vanes to eliminate slight cavitation which was observed through the inspection windows to the suction impeller by use of the stroboscope light, and subsequent runs showed that this had been effective in eliminating the slight cavitation formation. In the final runs, they intend to use a 15-vane diffuser instead of the 12-vane diffuser. They intend to decrease the clearance gradually, they will finish the runner and the water passages smoother, and modify the labyrinth seals. It is expected an efficiency between 88 and 89 percent will be obtained as a result of these changes.

Motor-Columbus Offices, Baden, Switzerland

On the morning of April 6, we went to the offices of the Motor-Columbus Company, where we were met by the following officials and engineers:

Dr. G. Hunziker, Director
U. Hochuli, Public Relations Officer
H. Giger, Engineer
Otto Hartmann, Senior Design Engineer and Project Engineer
J. Pillet, Test Engineer

After a general greeting by Doctor Hunziker, the history and development of the Motor-Columbus Company was traced by Mr. Hochuli. The formation of this company dates from the 1890's by the merging of the activities of two companies, the Motor Company of Switzerland, an engineering firm engaged in the development, promotion of electrical power; and the Columbus Company, also of Switzerland, which was engaged in the development of power primarily in the Latin American countries. Particular emphasis was given to their activities in connection with high head pumping installations and particularly pumped storage. Mention was made of one of the earlier pumped storage projects in Switzerland, which was installed in 1904. The activities of the company are strictly in engineering, similar to engineering firms in the United States. They engage in preliminary planning, design, and supervision of construction of the various hydroelectric projects.

Mr. Pillet, who is charged with overseeing the model test work for the Tehachapi Pump Lift now being conducted in Europe, gave a brief description of the work under way. This will not be repeated here as it is included under the two headings in the report pertaining to the model test work being conducted. In this connection, particular attention was directed to the problem of starting the large pumps. This is a problem which will be present regardless of the pumping scheme adopted and can be approached and solved separately. Further reference to this problem and four possible solutions is made in the following section reporting on the conference in Heidenheim, Germany.

Voith Plant, Heidenheim, Germany

On April 7, we assembled in the conference room of the Voith hydraulic laboratory and were greeted by the following officials and engineers:

G. Wernicke, Deputy Director of Turbine Department
Dr. R. Dziallas, Chief of Hydraulic Research Department
H. Philipsen, Chief of Project Department
O. Duscha, Chief of Design Department
Dr. W. Thuss, Deputy Chief of Hydraulic Research
Dr. W. Schramek, Chief of Pump Test Group
H. Offenhäuser, Test Engineer
H. Schleicher, Project Engineer
F. Wolfram, Project Engineer (Hydraulic)

In an opening statement, Mr. Wernicke traced the development of the Voith Company and the general scope of their work. They started originally with the manufacture of paper-making machinery and through this got into the field of manufacturing hydraulic machinery.

Dr. Dziallas then gave a general description of the laboratory setup, and of the work which had been performed in connection with the Tehachapi Research and Development Contract. The laboratory is equipped with a dynamometer with a power of 1500 kilowatts, with a speed of from 1500 to 750 rpm. This dynamometer is cradeled on oil pressure lubricated bearings and is sensitive to approximately 20 gram meters torque. The volumetric measurement is calibrated to a measured storage tank and is within the accuracy of one tenth percent. Speed is measured by an electronic counter of revolutions. The overall accuracy of the experiment is expected to be plus or minus 0.2 percent.

The matter of pump efficiencies was discussed and Dr. Dziallas said that the preliminary test model efficiency now obtained with the model operating at a reduced speed of 1500 rpm was 90.6 percent. From this he expected to achieve a prototype efficiency of from 92 to 92.5 percent. Asked if the company would guarantee some such efficiency, he answered in the affirmative, but pointed out that field measurements were subject to considerable more error probably in the neighborhood of 1.2 percent.

In a discussion of materials, it was stated that for the Lunersee Plant they had used 26 Cr-2C cast steel for the labyrinth. As will be noted under the discussion of the Lunersee Plant, these labyrinths developed excessive leakage which was probably due more to the drop in head across each stage of the labyrinth seal than to the material employed. They are now using a stainless steel 13 Cr-4Ni for similar work.

In reply to questions concerning delivery time, it was stated that 18 to 20 months were required for the Vianden pumps and that probably eight months would be required for the model study preceding the manufacture.

In reply to a direct question by Mr. Skinner regarding head per stage, Dr. Dziallas stated that there was no doubt in his mind that it would be practicable to construct a pump with a 360 meter head per stage. It must be noted, however, that this reply is necessarily conditioned upon certain considerations of water quality which probably more than anything else contributes to difficulties in high pressures across the seals and labyrinths.

In reply to a question by Mr. John Parmakian, the following table was set up on the blackboard and filled in by Dr. Dziallas:

ITEM	TYPE				
	1 st. ss	1 st. ss	2 st. ds	4 st. ss	1 st. ds
Discharge, cfs	556	556	556	342.5	-
Head Per Stage Feet	650	975	488	488	975
Speed, RPM	514	600	600	600	-
Specific Speed	2009	1724	2049	2170	1724
Prototype Efficiency	0.92 ± .003	0.91± .003	0.92	0.90± .003	0.92
Plant Sigma	NO	ESTIMATE	WAS	MADE	
Availability (Against Non-scheduled Outage)	SAME	VALUE	FOR	ALL	PUMPS

Following the conference an inspection of the laboratory was made. The two-stage double suction pump was seen operating at a reduced speed of 1500 rpm. This model had been damaged by a piece of iron being carried into the pump under a reverse flow test which damaged the impeller. Repairs were completed on the morning of our visit and in the afternoon the model was operating. At the time of this inspection, Dr. Dziallas called our attention to an aerodynamic model they were operating for investigation of conditions in the suction inlet of the pump. This was done in an effort to design the most efficient inlet piece. These investigations were both quantitative and qualitative. The latter included investigation of vortices within the suction eye which would, of course, reduce the efficiency and the steps that were taken to modify the model to eliminate these. At the time of our visit, the construction had been very nearly perfected. Only one small part remained where corrective steps were found to be necessary.

Following the inspection of the laboratory, a brief tour of the manufacturing plant was made. This plant is very well equipped with good production machinery, although some of it is quite old. The large boring mill in the plant, approximately 30 feet in diameter, has a date of 1929 on it. This machine survived the war and was left in place at the direction of the occupying forces. All this machinery is in good condition and is evidently producing satisfactory work. Incidently, at this plant it was noted that parts for the Pelton wheels for the American River Development were being crated and loaded on railway cars.

General Discussion of Model Results

In this section, I will make a preliminary comparison of the pump performances revealed by the tests. It must be realized that these are preliminary and, in case of the work carried out at the Sulzer Plant and the Voith Plant, are on the basis of operation at reduced speed. The results obtained at the Byron-Jackson Laboratory in Los Angeles were, of course, not observed but are reported to me by DMJM. For the conversion from observed model efficiencies to expected prototype efficiencies there are at least eight "step-up" formulae in use. Mr. Parmakian takes the position that each laboratory adopts a certain step-up formula that it has found to best correlate its work with observed prototype efficiencies. For the purpose of making the comparison in the following tabulation, however, I have adopted uniformly the Moody formula with the exponent of $\frac{1}{5}$. This step-up formula seems to have correlated a large number of experiments rather satisfactorily. The observed model efficiencies and the expected prototype efficiencies calculated in this way are given below.

Type of Pump	Model Efficiency	Probable Prototype Efficiency
1 st. ss	91.2	92.9
2 st. ds	90.6	92.4
4 st. ss	88.1	91.0

The above model results are believed to be quite comparable. All three laboratories have been carefully checked over and calibrated by Professor Leslie Hooper, employed by DMJM for this specific purpose. As far as I can see at this time the one possible discrepancy is the surface finish of the model made by Sulzer Bros. This model is not as highly polished in the water passages as the other models and may contribute to a slightly lower efficiency. In order to bring the results more in line, the Sulzer Bros. Company has agreed that they will refinish the surfaces of the water passages of their model more in conformity to the other model so that a direct comparison may be made. It is expected that this will be done in about four weeks.

Lunersee Pump Storage Plant

This plant has five, five-stage single suction vertical pumps operating under a head of 3150 feet. Each pump has a power demand of 58,000 hp discharging 144 cfs, operating at 750 rpm. Two of the pumps are manufactured by Escher-Wyss, two by Voith, and one by Sulzer Bros.

The plant was placed in operation in 1958. Both the Escher-Wyss and the Voith pumps were disassembled shortly after original installation and the impellers modified to bring the discharge up to specifications. No work was done on the Sulzer Bros. pump. After this, none of the units have been disassembled and there have been no unscheduled outages on account of pump performance. There have been annual inspections of the suction impellers through the manholes provided in the casing. There was evidence of slight cavitation on the suction impeller of the Sulzer pump which was corrected by surface finishing; no welding was performed.

The pumps have operated approximately 15,000 hours since installation of the plant to date. In spite of this comparatively low plant factor for the pumps, Mr. Kuhn, Plant Superintendent, emphasized that no maintenance work could ever be done during the down periods inasmuch as the units were on continuous standby subject to operation at any moment on call from the central load dispatcher for the Western European grid located at Cologne.

There has been a large increase in the labyrinth seal leakage on the two Voith pumps up to maximum of 117 and 154 liters

per second, respectively. The amount of leakage upon original installation is not known but probably was in the neighborhood of one quarter of this amount. On the Sulzer pump the similar leakage has increased from 49 liters per second upon installation to 61 liters per second at the present time. An examination of the details of the pump showed that the Voith pumps have a stepped labyrinth with 7 labyrinth passages while the Sulzer pump has the conventional interfingered labyrinth with 13 recesses. The greater increase in the leakage in the Voith pumps may be attributed to the greater head differential developed over each labyrinth passage as compared to the Sulzer pump.

The pumps are started with the casing filled against a closed discharge valve by means of the hydraulic torque converter coupling connecting the shaft of the motor-generator and the Pelton wheel with the pump. When the pump has been brought up to synchronous speed this coupling is rigidly locked with a sliding jaw and the torque converter is drained. At this point the discharge valve is opened and the pump goes into normal service. This change-over is accomplished quite smoothly and in about two minutes' time.

Mr. Kuhn pointed out that the breakers on this system are arranged for automatic reclosing after delay of 0.4 seconds. On this momentary interruption the motors do not drop out of step but pull back into synchronization after breakers reclose. The motors are the solid pole construction which is prevalent in European practice but, in this case, with a portion of the pole face made of laminations and fitted with ammortesseur bars.

Rodund Plant

In the afternoon of April 8, under the direction of Mr. Lauger, the Plant Superintendent, we visited the Rodund Power Plant. There is installed in this plant a horizontal two-stage double flow pumping unit of 53,600 hp operating at 500 rpm. This unit, manufactured by Voith, delivers 353 cfs against a head of 1,148 feet. This pumping unit was placed in operation in 1952, and since that time has performed adequately with only normal maintenance work being performed.

Tierfehd Plant

April 9, 1965 - This plant was inspected under the direction of Mr. Bochtiger, Plant Superintendent. This plant is primarily a power plant but has installed two pumping units for the delivery of water from a low level reservoir to a high level reservoir when the inflow exceeds that which can be used in generating power from the low level reservoir. The pumping units are three-stage single flow pumps of 22,800 hp, operating at 1,000 rpm, delivering 97 cfs against a head of 1,775 feet. Of special note is the fact that the suction pressure is 1,558 feet so that the maximum head on the pump casing is 3,330 feet. This is one of the highest heads

encountered in any of the pumping plants.

The pumping units are started under 60 percent voltage with the casings filled with water and against a closed discharge valve. Actual observation of this starting procedure showed it to be one of the smoothest of any that we had witnessed.

These units, manufactured by Sulzer Bros., have been in operation for a little over a year and the two units have operated 800 hours and 600 hours, respectively. This comparatively short period of operation precludes any estimate being made of the maintenance work which might be required. Of course, the high suction pressure precludes the possibility of there being cavitation on the suction impeller.

Etzelwerk Plant

On the afternoon of April 9, 1965, we visited this plant under the direction of Mr. Ziegler, Plant Superintendent. This is one of the older plants, having been placed in operation originally in 1947. It has four Pelton wheel-driven generating units and two Pelton wheel-driven generating and pumping units. One half of the plant is connected to the power grid and the other half is devoted to the single-phase railway system which operates at 6-2/3 cycles per second. This establishes the highest possible speed of the storage pump as 500 rpm. The pumps are five-stage single suction vertical units operating against a head of 1,475 feet delivering 92 cfs and 113 cfs, respectively and requiring 20,100 hp and 25,500 hp, respectively. The pumps are located below the Pelton wheels and are connected to the shaft by means of a jaw coupling, manually controlled. A turning gear, to bring the jaw coupling into coincidence, is also manually controlled. The connection is made at standstill before each cycle of pumping operation.

The pumps are started with the casing full against a closed discharge valve by admitting water to the Pelton wheel after the units have been coupled together. Upon being brought to synchronous speed the field of the motor is energized and the Pelton wheel is shut off and the discharge valve opened. This is a somewhat time consuming operation and is noisy, but it has evidently been satisfactory. Evidently no serious operating difficulties have been encountered although the operation is somewhat cumbersome due to the inherent features of the design as noted heretofore. The two pumps have operated 18,350 hours and 22,840 hours, respectively, with approximately 200 starts per year. The pumps were manufactured by a joint venture of Sulzer and Escher-Wyss, the latter firm manufacturing the couplings.

Conference at Zurich

On April 9, following our return to Zurich, Mr. Golze' called a conference in the evening to discuss the inspections we

had made during the week. Mr. Golze' called upon each of the conferees in turn as to their impressions and conclusions drawn from the inspections.

In response to inquiry Mr. Skinner stated that the two-stage double flow pump seemed to perform exceptionally well, both in the prototype installations and in the model which was constructed by Voith at Heidenheim. He thought that this would probably be a proper pump to select for the two-lift system. He further stated that if the condition indicated that a single lift system should be adopted, that the four-stage pump would probably be satisfactory. He expressed a little disappointment, which I think was shared by everyone, that the efficiency of the four-stage pump, as now being model tested by Sulzer, came out rather low. In the conference at Winterthur, Mr. Strub had stated, however, that this was probably the best that they could do with the four-stage model. Mr. Skinner expressed a preference which was evidently shared by Messrs. Winn and Rockwell for the horizontal configuration of the two-stage double flow pump.

At this point Mr. Gartmann interjected his thought that it might be advantageous to have Voith make a four-stage model pump with their impellers and return passages. He had proposed this once or twice in the past, but it had so far been rejected and the consensus, even at this time, was that there would probably be little to be gained by such a procedure.

Mr. McBride stated that while he had always had a preference for vertical shaft pumps he could see the advantages to be gained by the horizontal shaft configuration. At this point it was again pointed out that the system should first be determined and the pumps adapted to it rather than to proceed with the pump design and make a system to fit the pumps. I pointed out that this is our present procedure and that the only reason for proceeding with the pump model studies simultaneously with the system investigation is due to lack of time.

In response to inquiry, Mr. Winn added little to what had been previously voiced. In general he confirmed the previous statements.

In response to inquiry, Mr. Rockwell pointed out that the pump starting problem was probably one of major significance which had been investigated very little up to this point. He pointed out there was a serious disagreement between American manufacturers as to what could be done with starting these motors of this size directly across the line and that this again was in variance with the European practice. He pointed out that this was an additional advantage of the two-stage horizontal configuration pump in that the casing could easily be unwatered for starting. He mentioned several alternatives for starting the pump motors as follows:

1. Reduced voltage starting.
2. Starting with a small Pelton wheel coupled to the pump shaft.
3. Starting with an auxiliary hydroelectric generating unit so that starting could be at zero frequency.
4. Starting with an electrically driven generator set, similar to 3.

At this point I stated that Item 3 was already under active consideration by the Department and at the moment appeared to be the most favorable.

Mr. Rockwell thought that the electrical starting of the pumps from an independent local generator would also assist in the initial filling of the penstocks or subsequent filling of them whenever they had been drained. I was somewhat reluctant to accept such a proposition and stated that we would definitely have penstock filling pumps installed. He agreed that this would be a better plan and offered no objection.

In response to inquiry I stated that I had little to offer at the moment. I emphasized that I had no preconceived ideas as to what the system or the pump configuration should be but that on our preliminary studies it appeared that a vertical configuration would be the most advantageous.

In response to inquiry Mr. Gartmann stated that there was undue emphasis on the matter of specific speed. He pointed out that this was a design parameter and had little or no relation to the pump reliability or wear. In his estimation a more accurate criterion for reliability is actual rotational speed and the peripheral velocity of the impeller tip. The latter is, of course, directly related to head per stage.

At this point Mr. Skinner stated that since we were going to have four pumping plants in series anyway; i.e., Buena Vista, the two Wheeler Ridge plants, and one Tehachapi plant, adding another plant should not increase the problems materially. I pointed out that there was more storage available between the other plants, say in the order of 1-1/2 or 2 hours but that the storage between the two plants of Tehachapi lift would necessarily be extremely limited; we had tentatively established a storage capacity of plus or minus 15 minutes of flow. Mr. Rockwell stated that this did not disturb him greatly since overpumping by the lower plant would only result in spilling water from the intermediate storage forebay which would not be catastrophic. I pointed out that while overpumping was not a problem, underpumping and running the second plant dry would lead to severe damage to the pumps. I cited the instance at Tierfehd, where only 30 seconds of the operation of the pump without sufficient water supply destroyed the shaft sleeve seals and necessitated a major repair job.

In general discussion there appeared to be some confusion between an intermediate storage to balance out inequalities in flow and momentary stoppages of pumps with the matter of the requirement

for surge tanks. I pointed out that surge tanks at the end of the delivery lines would be required in any case in order to establish a point of atmospheric pressure.

Mr. Skinner stated that the Bechtel Corporation had made no specific recommendations as to specific speed of pumps. I pointed out that although they had not explicitly made such a recommendation they had implicitly done so by recommending single-stage pumps for the two-lift concept. This would result in a lower specific speed in the order of 1450.

The matter of providing spare units as such came up again for discussion. It appears very difficult to explain the situation to these people. The 7-1/2 percent reserve capacity which we have built in throughout the system may not be adequate. It may finally be necessary, as a matter of policy, to make provision for the installation of one additional unit.

Vianden Plant

This is the largest pump storage plant yet constructed, containing nine horizontal shaft units. Each unit consists of a Francis turbine, a motor-generator, a small Pelton wheel for starting the pumps, and a two-stage double suction pump. The pumps operate at 428 rpm with a horsepower of 92,800 delivering 803 cfs against a rated head of 879 feet. The pumps are started with the casing unwatered by means of the small Pelton wheel and brought up to synchronous speed. When speed and synchronism of the motor has been reached a sliding jaw coupling is automatically engaged. The air is then released from the pump casing which is filled with water and the pump operates against the closed discharge valve. Immediately then the discharge valve is opened and normal pumping operation begins.

Five of the pumping units were built by Escher-Wyss and four by Voith. The Escher-Wyss pumps are built with horizontal split casing, while the Voith pumps are built with a solid casing and dismantled from the end. Mr. Kass, the Plant Superintendent, said that he greatly preferred the horizontal split case pump from the standpoint of maintenance.

The plant was first put in operation in October 1962, and the last unit completed and put in operation in June 1964. The longest operating experience is with Pump No. 2, which has to date 6,200 hours. There has been some cavitation in the suction impeller of the Voith pumps; none in the other pumps. This cavitation has not necessitated extensive repairs or shut down for maintenance work. A piece of the diffuser vane from Pump No. 1 was carried into the penstock and later on the generating cycle was carried into the turbine, damaging the runner. The unit was shut down at the time of our visit and the runner was being repaired. At the same time Unit No. 4 was out of service and the repairs to cavitation in the turbine runner were being made. It is planned in the future to

replace the diffusers between the first two stages on all the pumps with a different construction to preclude future occurrences such as happened to Unit No. 1

In the horizontal shaft pump units the entire weight of the rotating assemblies is carried by the end bearings. The sealing sleeves between stages 1 and 2 are grease lubricated and act as guide bearings as well. The first stage impellers are 13-1 stainless steel; and the remaining parts are carbon steel. The water is noncorrosive and contains a minimum of suspended matter. The wear rings are bronze, mating with stainless steel rings on the impellers. While not connected to the pumps, an interesting feature of this plant is the expansion joint at the turbine spiral case inlet. This expansion joint, a device patented by Escher-Wyss, provides freedom for expansion at the joint but at the same time is balanced to nulify the hydrostatic pressure across the joint. This is accomplished by external balancing chamber surrounding the pipe to which the head water pressure is admitted.

Ffestiniog Plant

Being unable to visit the Ffestiniog Plant, we called on Mr. Headland of the firm of Kennedy and Donkin, Consulting Mechanical Engineers, who designed the mechanical features of this plant for the owners, the Central Electricity Generating Board. At this conference, Mr. Headland was questioned extensively as to the design and operation of the pumping units in this plant.

Mr. Headland stated that the vertical configuration of the units was selected in order to make the shortest possible length of the plant. Selection of these units also accommodated the tail water conditions required for both the pumps and the turbines; the turbines requiring considerably less submergence than the pumps. Two stages for the pumps were selected in order to secure a reasonable head per stage of approximately 500 feet. The double suction was adopted both in order to give a proper specific speed and to eliminate hydraulic axial thrust. Bids were taken for units with both 300 and 428 rpm rotated speed with the adopted speed 428 proving most economical. Reversible pump-turbine units were considered at the time the plant was designed; however, at that time they did not consider there was enough experience with units of that head, (approximately 1,000 feet). There is no problem at this installation from either corrosive or erosive water.

For manufacturing the pump-turbine generating units for this plant, three joint ventures were encouraged by the owners. These joint ventures consisted of an English firm and a continental firm experienced in the manufacture of storage pumps. Bids were invited in 1957, and the job was awarded to the joint venture of English Electric Company and Sulzer Bros. Under this arrangement the impellers and diffusers were manufactured by Sulzer Bros. and

the remainder of the pumps being manufactured by the English Electric Company. A minimum efficiency of 90.5 percent was specified, which efficiency has been achieved or exceeded in the units as now operating An optional item included in the bidding schedule was the performance of prototype tests by the manufacturer of the pumps. To date these tests have not been performed. This being a true pump-storage project, it is possible to measure the overall efficiency of the whole project by the electrical energy produced and consumed. On this basis it has been estimated that the pump efficiency exceeds that specified. Another requirement of the specifications was performance of model tests by the pump manufacturer and approval by the owner. Mr. Headland stated that the actual efficiency estimated as noted above closely corresponds to that determined from the model tests.

In this installation the pump is connected to the turbine and generator shaft by a sliding jaw coupling. In pumping operation this coupling is engaged while at a standstill and the unit brought up to speed and synchronized by the turbine with the pump casing unwatered. After the unit is synchronized and electrically the turbine is shut off, the turbine casing unwatered, and the water admitted to the pump casing and the discharge valve opened enabling normal pumping to continue. Mr. Headland stated that the time consumed by this operation was of little importance and he did not think that, if the plant were being designed again, hydraulic couplings would be used.

The first pump was put in service at the end of 1961, and the last one near the end of 1962. Since that time the operation has been satisfactory and only routine maintenance has been required. Inspection plates have been removed and the suction impellers inspected from time to time. There has been slight cavitation of the upper impellers. While it was originally planned to operate the units approximately 1,500 hours per year, it has actually been found advisable to operate them about 2,000 hours per year.

Upon being asked what changes he would make if he were designing the plant again, Mr. Headland stated that probably more care would be used in the design of the inlets to the pumps, including model studies of the hydraulic passages. He did state, however, that he thought it would not be necessary to have a strictly symmetrical design for the inlet passages and the bifurcation. He also stated that he preferred the English Electric straight-through valves used on the discharge lines to the sphere valves, and would continue to use them.

Conference at National Engineering Laboratory

On April 15, 1965, a conference was held in the conference room of the National Engineering Laboratory, East Kilbride, Scotland. Mr. Skinner, Chief Engineer and General Manager of the Metropolitan Water District, presided. The National Engineering Laboratory is

represented by Dr. Sopwith, Dr. Grundberg, Head of the Division of Hydrodynamics, and Dr. Spencer, Assistant Head of the Division of Hydrodynamics and the person immediately concerned with the testing program, now under way, as well as other members of the staff. A complete roster of attendance is given in an attachment to this memorandum. In addition, the Metropolitan Water District, the Bechtel Corporation, the Division of Water Resources, and Daniel, Mann, Johnson, and Mendenhall were represented.

A full report of this meeting will be prepared by Daniel, Mann, Johnson, and Mendenhall and submitted separately; the essentials of the conference pertinent to the points immediately under consideration will be presented herein. The semi-confidential progress report No. 3, distributed at the conference, gave the results of testing of seven separate pump models procured from manufacturers in both the United States and in Europe. During subsequent discussion sufficient data was given to enable us to identify the designers and manufacturers of the various models designated in the report as A through F, with additional report at the meeting on a seventh model which had only recently been tested and not included on the report. In addition to these seven models, the Bechtel Corporation planned to procure three additional models for testing as soon as the 4,000 hp test apparatus has been constructed. Later this year, the Department will make available to Bechtel Corporation for testing at this laboratory the three pump models now being tested under the DMJM Contract.

Professor Hanz Gerber summed up the purpose of the test being conducted at the National Engineering Laboratory in the following way:

1. To compare the test results obtained with those previously found in the manufacturer's own laboratories and thereby in effect indirectly calibrate the manufacturer's laboratories.

2. To determine a relationship between the efficiency and the specific speed.

With respect to the first objective, it has been generally found that the results obtained in this series of tests agreed very closely of those previously obtained by the manufacturers.

With respect to the second objective, the number of tests conducted was too small to give conclusive results. Figure 6 of the preliminary report, which proported to show such a relationship, was during the conference found to be in error inasmuch as the specific speeds of the multistage pumps tested were not specific speeds of the runners and hence not indicative of this relationship.

Later in the conference, Mr. Skinner stated that the interests and objectives of Metropolitan Water District, with respect to Tehachapi Lift, might be stated in three general categories:

1. Selection of the pumping system; either single lift or two lift.

2. Providing the best possible and most comprehensive procurement specifications in order to secure satisfactory pumping equipment.

3. Making a general contribution of engineering knowledge for the benefit of both the State Water Project and for such future pumping installations as the Metropolitan Water District might require themselves.

Following this part of the discussion, Dr. Spencer produced and distributed copies of curves showing the relationship on one of the models between pump performance and the cavitation number (sigma). These are the familiar "sigma-break curves". After general discussion, it was concluded that this was an inaccurate and not a conservative way of determining the required sigma for the plant. Actual observation of the inlet side of the impeller through a transparent window under stroboscopic light is much preferred. In this connection also, members of the NEL staff pointed out the importance of operating with de-aerated water.

Interspersed between two sessions of the foregoing conference, an inspection trip was made through the laboratory facilities. The National Engineering Laboratory is certainly well equipped with the latest and highest precision equipment and instrumentation. This fact, coupled with the competence of the supervisory operating personnel, would leave little doubt as to the accuracy of results obtained here. The addition of the 4,000 hp dynamometer, which has been procured and the foundation for which is now being constructed in a building to be placed between the two existing wings of the laboratory building, will enable testing of the largest models conducted with the same degree of precision.

Conclusions

1. As a result of the foregoing inspections and conferences, it is concluded that there is no question that completely adequate and reliable pumps can be designed and manufactured for either lift scheme selected for the Tehachapi Crossing.

2. Multistage pumps will be required for either of the crossing schemes now being considered by the Department.

3. To design and manufacture the required pumps it is essential that the technical abilities and manufacturing techniques of the European manufacturers be brought to bear on the problem. This may be accomplished by a joint venture arrangement similar to that employed by the CEGB for the Ffestiniog units.

4. Results of tests now being conducted for the Bechtel Corporation at the National Engineering Laboratory will have no significance in the selection of the pumping scheme for the Tehachapi Lift.

5. The National Engineering Laboratory is a well equipped, competently staffed, independent hydraulic machinery laboratory which can be utilized to advantage by the Department for any tests which may be found necessary in the future.

E OF CALIFORNIA—RESOURCES AGENCY

EDMUND G. BROWN, Governor

PARTMENT OF WATER RESOURCES
BOX 388
AMENTO

May 8, 1965

Mr. Alfred R. Golze'
Chief Engineer
Department of Water Resources
P. O. Box 388
Sacramento, California

Dear Mr. Golze':

The Tehachapi Crossing Consulting Board was convened in Bakersfield, California, on May 2, 1965, and proceeded to the Tehachapi area to examine on the ground the alternative alignments under consideration and the results of the latest geological studies and site explorations pertaining thereto.

Our Board reassembled in Sacramento on May 4, and had the opportunity to confer with Dr. Hugo Benioff, Chairman of the Board for Earthquake Analysis, and to hear carefully prepared and valuable presentations by the Metropolitan Water District and their consultants, the Bechtel Corporation, by Daniel, Mann, Johnson and Mendenhall, your consultants, and by the staff of your Department.

These presentations covered many fields of investigation and preliminary planning, some research and development, and detailed studies of system reliability and costs of the alternative alignments and their various features. Over the past several years much of this material had been considered by our Board on previous occasions but it has all been reviewed and considered by us in the light of more recently developed material, alternative plans and the well considered professional opinions of able engineers.

The planning of the Tehachapi Crossing has reached such a degree of refinement, through eliminating the unsuitable while retaining the feasible elements, that a choice among the schemes and major features of the remaining Ridge alternatives becomes a matter where judgment plays a major role in arriving at a final engineering preference. We are fully aware that the margin of preference is, in some areas, a narrow one, and our remarks, as given below, are presented after weighing carefully all elements of the problem.

Question 1: "Does the Board concur in the recommendations of the Department of Water Resources' 'Report on Alternative Locations of Tehachapi Lift System', April 1965?"

Answer: No further consideration of the Pastoria Canyon routes is warranted. It is believed that detailed reasons for this position are not required since the recent site explorations adequately support this conclusion.

We recommend that future design be devoted to the Ridge single-lift scheme with underground discharge pipes. Our reasons for this recommendation are given in the following discussion:

I. SITE CONDITIONS

a. Geology

In general, the overall site geology in the Ridge area is favorable and reasonably good rock is found at relatively shallow depths. Geologic conditions are quite similar for the two-lift and single-lift Ridge schemes.

The effect of geology is largely a function of the number of structures, surficial or underground features, and the actual specific location of structures, particularly on the surface.

Considering the foregoing, it is obvious that the two-lift scheme has over twice the number of exposed surficial structures, including the small, off-line reservoir, and an additional section of tunnel. While the dam poses no material problem in foundation and spillway location, its chief hazard to the scheme involves slope wash, debris and small slides into the reservoir that will slowly reduce capacity and occasionally provide a suspended solids problem that would increase wear on pumps.

Hence, the geology is more favorable to the single-lift scheme.

b. Seismicity

Both schemes have the same exposure to shaking and fault rupture. The probability of actual displacement is very low, but the area may be severely shaken several times during the life of the project.

Here again the location of the structures and the number of structures are important. The two-lift scheme, having over twice the number of structures, offers over twice the chance for seismic damage.

The possibility of damage to the small off-line reservoir due to shaking, overtopping waves from seismically triggered landslides, or partially filling the reservoir with slide debris, is ever present even during light shocks which are more numerous than major shocks.

The one-lift Ridge alignment, with underground discharge lines, has only the one pumping plant located on the surface and most of the conveyance system is underground where, in the best rock of the area, the effects of shaking will be minimized.

Hence, with regards to seismic hazard, the single-lift Ridge scheme with underground discharge lines has a marked superiority.

II. DISCHARGE LINES

Explorations have indicated that the discharge lines can be located in tunnels in hard and strong gneissic diorite rock. Considering seismic effects and reliability in operation and maintenance, discharge lines in tunnels are preferred for safety and dependability over surface installations which, in some locations would be in weathered or sheared material on steep slopes. We note that the Consulting Board for Earthquake Analysis in its report dated April 8, 1965, concurs in this preference for locating discharge lines in hard rock tunnels.

The Board believes that for the single-lift scheme discharge lines can be so arranged and designed that a dependable job can be obtained with high quality steels available for such construction.

III. MECHANICAL FEATURES

a. <u>Pumps</u>

It is our belief that the pump industry can design and build pumps for the single or double-lift schemes that will be efficient and reliable, and will give satisfactory service for many years. This conclusion has been reached after very serious consideration by our Board. Although we are aware of some views which diverge from this conclusion, we believe that the preponderance of technical opinion, as expressed by those who have

appeared before us and by other experts and pump designers who were contacted in Europe, supports our conclusion.

Many details of pump design have been presented in support of some of the divergent views but we feel that the apparent problems discussed can be solved effectively by design and verified by prototype testing.

Supplementing the preceding general views the following more specific comments are noted. In its April 1965 report, the pump model research contractor DMJM stated:

> "Regardless of the pump type finally selected, be it a single-stage, two-stage or four-stage pump, there is no doubt whatever that the pump industry will be able to design and build pumps for Tehachapi that will be reliable and will give satisfactory service over the next 50 years."

The following statement is included in the May 1965 report of Professor Hans Gerber, Consultant to the Bechtel Corporation:

> "We think that the choice of a single-lift, a two-lift or a three-lift solution is first of all a topographical, geological and seismic problem. It should clearly be stated that, independent of costs, it would be possible for all three lift solutions to have reliable and rugged pumps built, and for all these pumps long years of experience of different kinds are available."

The following statement is included in the April 1965 report of Professor L. C. Neale to the Bechtel Corporation:

> "The present (pump model) program has shown a good correlation with the manufacturers' laboratories. Results at best efficiency point are within 1/2 percent."

During the past month one of our board members met with the pump designers in Europe from the Escher-Wyss Company and Sulzer Brothers in Switzerland and the J. M. Voith Company in Germany. Each of these companies stated that they would be willing to bid on a high performance prototype pump for any of the Tehachapi lift concepts.

The efficiencies predicted for the model test pumps have been realized and there is also assurance that the expected prototype performance can be attained for each of the pump types.

The probability that a suitable single-stage pump for a 1,000-foot lift may be developed in the next few years for the two-lift system is acknowledged.

b. Control Equipment

Each pumping unit for either one of the schemes considered will have essentially the same control equipment for the pump itself and for the discharge and inlet valves. If the Ridge two-lift scheme is used, special monitoring of Plant No. 1 will be required to prevent overflow of the relatively small off-line reservoir at Plant No. 2. Similar special monitoring will be required at Plant No. 2 to guard against low water on the suction side of the pumps.

In regard to the Ridge single-lift scheme, this type of special monitoring would not be needed. The inherent advantage of the single-lift control system, however, would be in the smaller number of pump controls required and the centralized location thereof.

IV. ELECTRICAL FEATURES

a. Motors

The problems encountered in selection of motors for the pumps are essentially the same for any of the schemes, differing only in degree. The principal problem which departs to any extent from previous practice is that of motor starting. The simplest and most direct method is that of applying full voltage to the motor terminals. This will require further investigation of the capabilities of motor manufacturers and of the available power supply to determine feasibility. In any event several alternative plans for starting are available, following the guide lines of previously built installations. Other than starting, the motor problems are conventional and should pose no unusual difficulties.

b. Power Supply

The power supply for the upper pump station of a Ridge two-lift scheme requires the construction of a large substation on an expensive and restricted site on the ridge, and transmission lines thereto. The Ridge single-lift scheme does not require these features and from such viewpoint is to be preferred.

c. Control Equipment

The Ridge two-lift scheme, because it requires two plants, involves a considerably greater amount of control equipment and number of control circuits than the Ridge single-lift scheme, although not twice as much. The problem of initiating series operation of the two plants under the Ridge two-lift scheme and of protecting against any possible malfunction is magnified. For these reasons the Ridge single-lift scheme is preferred.

V. COSTS

In considering the estimated costs of the Ridge schemes proposed by the Department, and those outlined by Metropolitan's engineers in their May 5, 1965 presentation, it has been noted that the several alternatives have closely comparable capital costs. The greatest cost variation between schemes amounted to about 12 percent. It is doubtful if any cost estimate at this stage of the planning could be more accurate than this differential and, accordingly, it is concluded that for practical purposes, all of the schemes presented have about the same capital cost.

Similarly, the estimated annual operating costs for the several alternative schemes have been found to be virtually identical, the maximum differential being less than 4 percent.

Accordingly, the Board concludes that estimated costs of construction and operation have been shown to have minimum influence on the choice of scheme.

VI. DEPENDABILITY

In all of the presentations and reviews, emphasis has been placed on the need to select a lift scheme which will offer maximum dependability and reliability. The Board fully concurs with this objective and, in summary, has evaluated the several basic elements of the Ridge single-lift scheme in this reference as follows:

a. Surface Pumping Plant

Least subject to uncertainties of construction or of access for major repairs.

b. Four-stage Single-lift Pumps

No more complicated than two-stage, double-flow pumps and fully as capable of being ruggedly constructed and reliably operated.

c. Single-lift Discharge Lines

Can be as reliably designed and constructed to give safe service as any other system by utilizing high quality steels and conservatively sizing the manifolds and branches.

d. Controls for Single-lift

Least extensive and least complicated and therefore most reliable.

e. Power for Single-lift

Transmission, transformer and switchyard facilities serve a single location and therefore are least exposed to outages.

f. Water Storage for Single-lift

Requires only a single forebay and therefore at least halves the problems and hazards of reservoir operation.

g. Personnel for Single-lift

Requires minimum use of personnel for surveillance and operation, thus minimizing opportunity for human errors in operation.

h. System Operation for Single-lift

Provides maximum simplicity of layout, and offers least opportunity for misoperation. This is judged to be of special importance in relation to coordination with the operation of the several upstream pumping stations and the several downstream pump and generating plants, all of which operate in series with the Tehachapi lift.

Question 2: "Does the Board have any additional comments to make after giving due consideration to the work of Bechtel Corporation and the recommendations of Metropolitan Water District's Report 'Tehachapi Pump Lift', May 5, 1965?"

Answer: We have given close attention to the work of the Bechtel Corporation and the Metropolitan Water District Report

"Tehachapi Pump Lift", May 5, 1965, and wish to commend those organizations for the extensive investigations and valuable information they have contributed to our overall study of the Tehachapi lift. All of their contributions have been carefully considered in the formulation of the judgments expressed in the foregoing paragraphs.

In conclusion, it is the sense of the Board's collective judgment that the Department can now undertake with confidence the final design of a single-lift scheme along the Ridge alignment.

Very truly yours,

s/ John R. Hardin
John R. Hardin, Chairman

s/ Russell G. Hornberger
Russell G. Hornberger

s/ T. M. Leps
Thomas M. Leps

s/ E. C. Marliave
E. C. Marliave

s/ John Parmakian
John Parmakian

(Absent)
Louis G. Puls

s/ Robert Sailer
Robert Sailer

GENERAL NOTES:

1. HORIZONTAL CONTROL IS BASED ON CALIFORNIA COORDINATE SYSTEM, ZONE V.
2. VERTICAL CONTROL IS BASED ON U.S.C.&G.S. 1929 DATUM.

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GENERAL PLAN

APRIL 1965

GENERAL NOTES

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2 VERTICAL CONTROL IS BASED ON USC&GS 1929 DATUM

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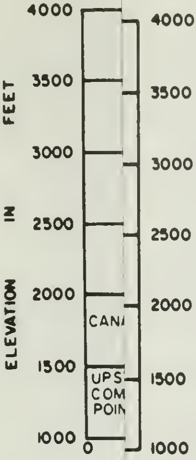
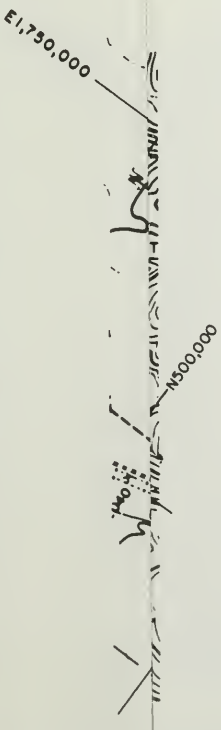
ALTERNATIVE LIFT SYSTEMS

GENERAL PLAN

APRIL 1969





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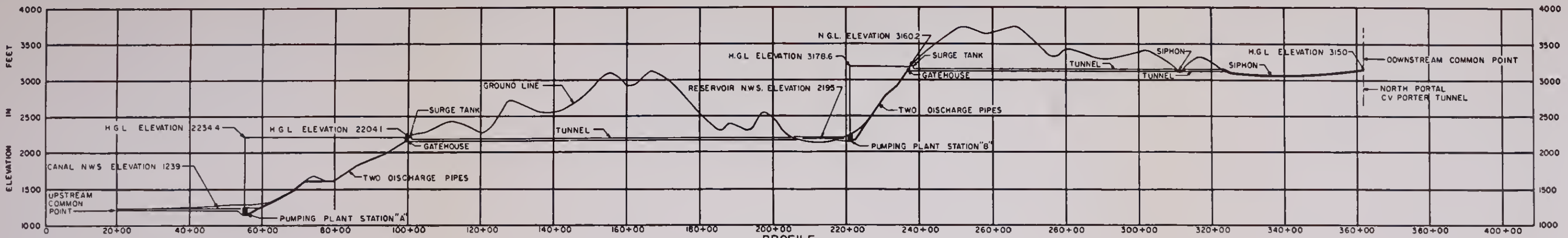
ALTERNATIVE LIFT SYSTEMS

SYSTEM I
PASTORIA TWO EQUAL LIFT
PLAN AND PROFILE

APRIL 1965



PROFILE

HORIZONTAL SCALE OF FEET

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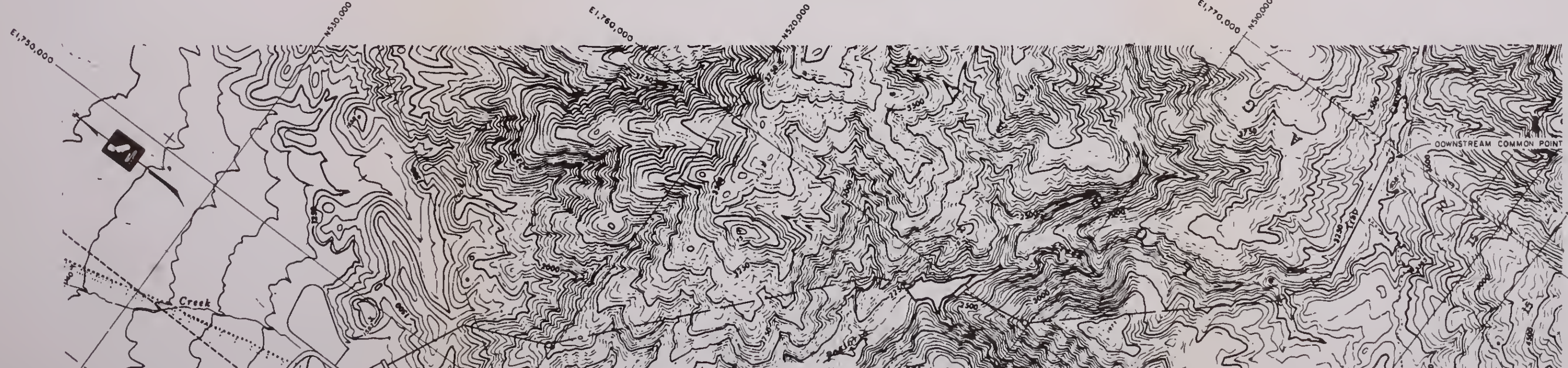

PLAN

SCALE OF FEET

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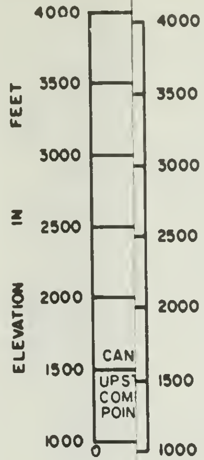
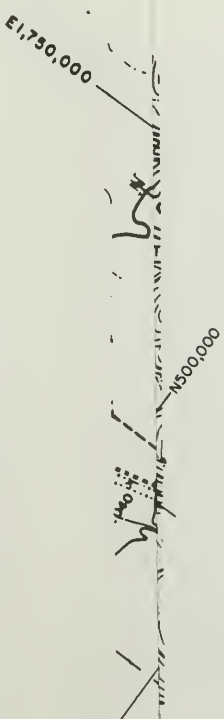
SOUTHERN DISTRICT

TEHACHAPI DIVISION
ALTERNATIVE LIFT SYSTEMS

SYSTEM I
PASTORIA TWO EQUAL LIFT
PLAN AND PROFILE

APRIL 1965





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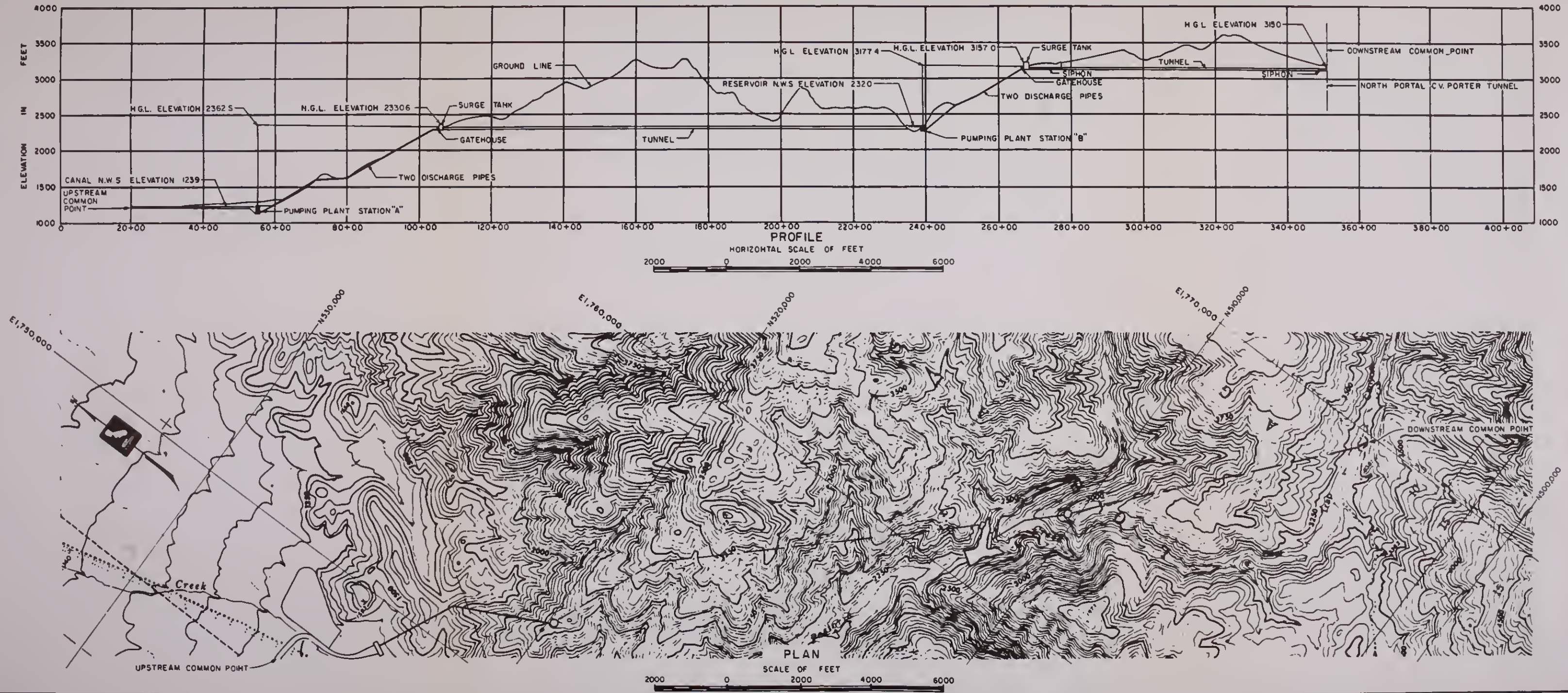
ALTERNATIVE LIFT SYSTEMS

SYSTEM 2
PASTORIA TWO LIFT
PLAN AND PROFILE

APRIL 1965



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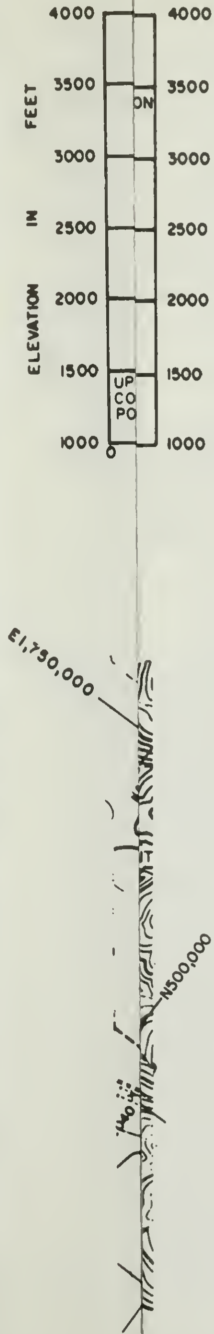
ALTERNATIVE LIFT SYSTEMS

SYSTEM 2
PASTORIA TWO LIFT
PLAN AND PROFILE

APRIL 1969



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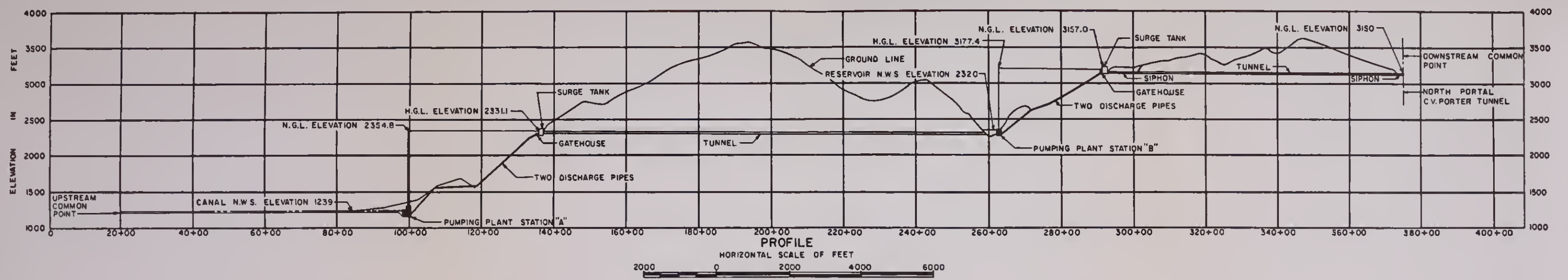
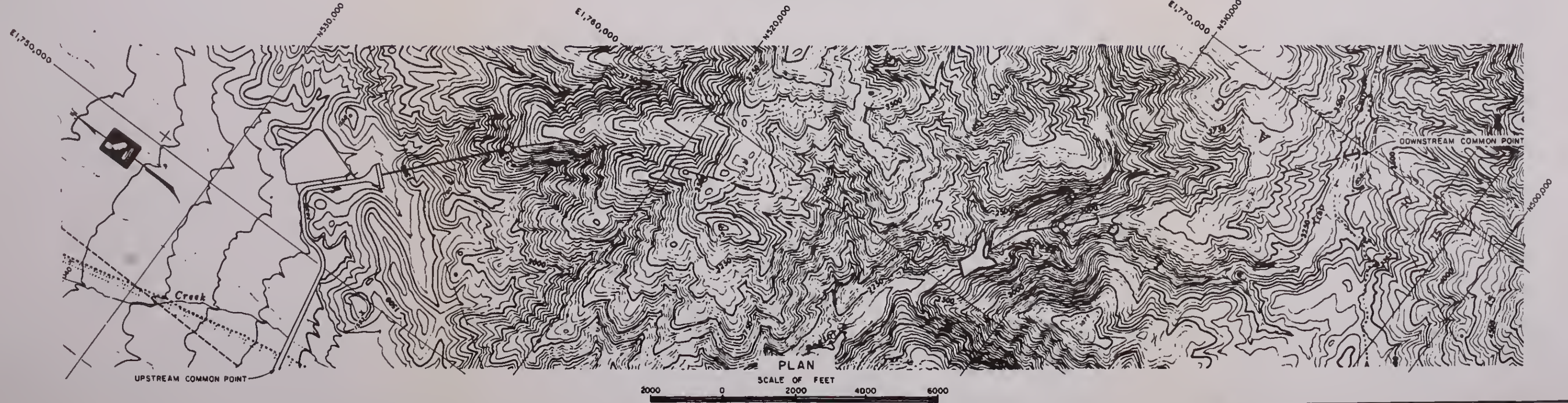
ALTERNATIVE LIFT SYSTEMS

SYSTEM 3
RIDGE–PASTORIA TWO LIFT
PLAN AND PROFILE

APRIL 1965





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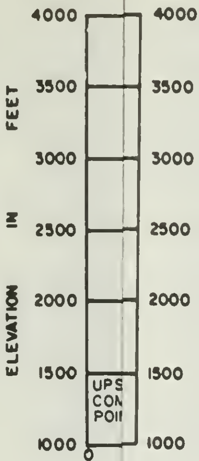
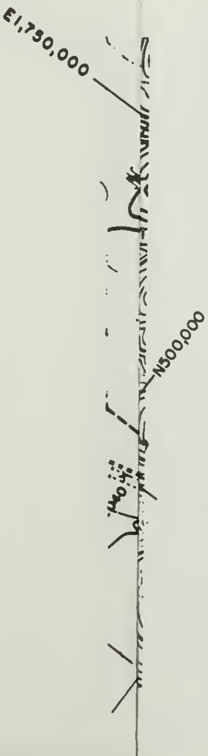
ALTERNATIVE LIFT SYSTEMS

SYSTEM 3
RIDGE-PASTORIA TWO LIFT
PLAN AND PROFILE

APRIL 1965





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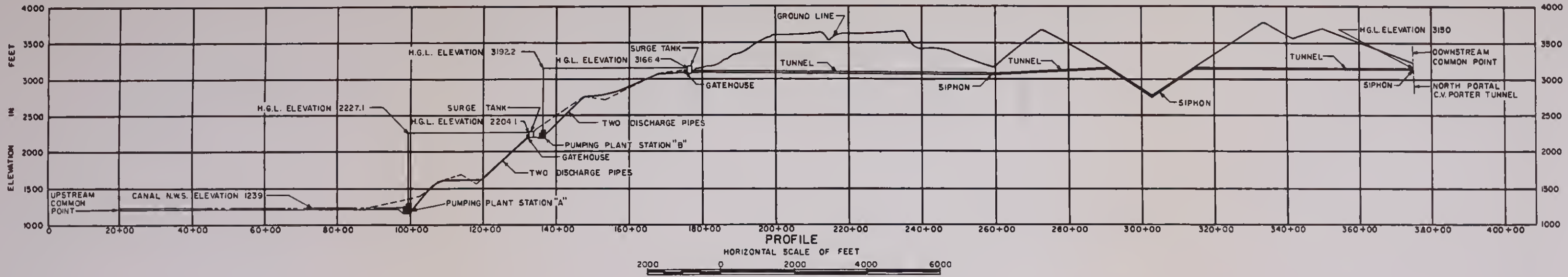
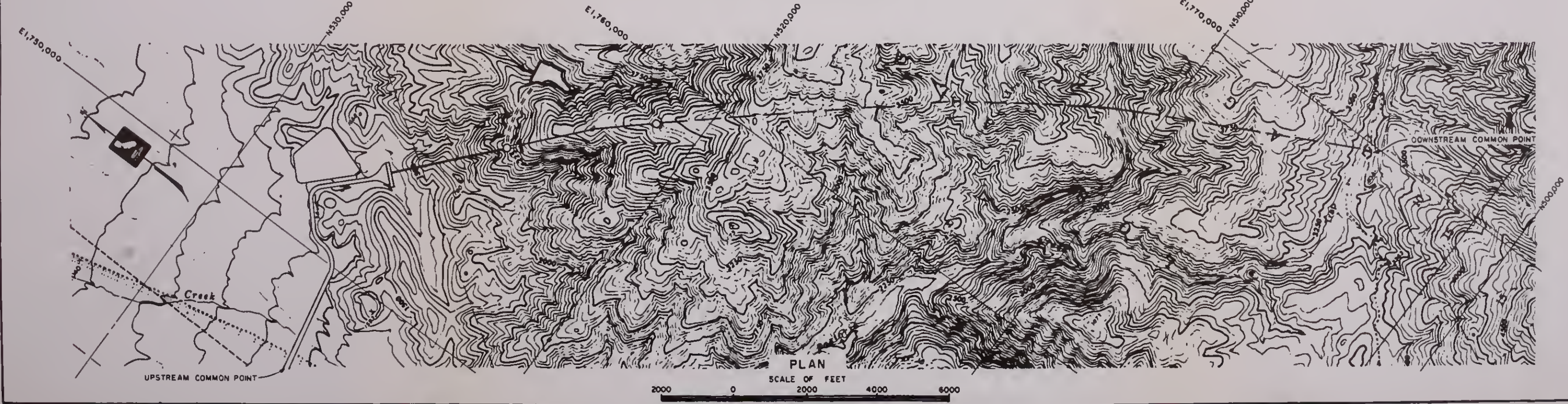
ALTERNATIVE LIFT SYSTEMS

SYSTEM 4
RIDGE TWO EQUAL LIFT
PLAN AND PROFILE

APRIL 1965





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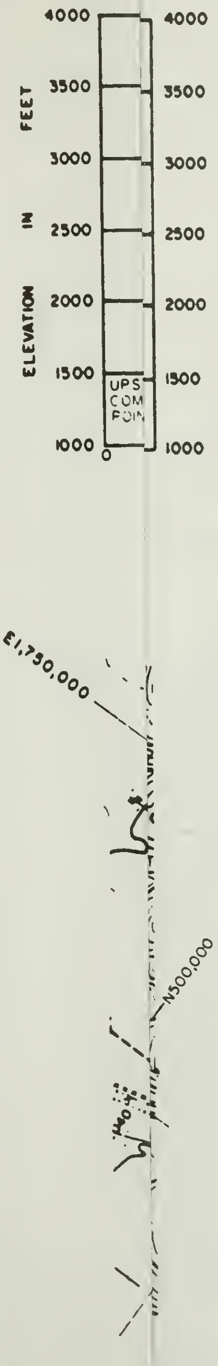
ALTERNATIVE LIFT SYSTEMS

SYSTEM 4
RIDGE TWO EQUAL LIFT
PLAN AND PROFILE
APRIL 1965



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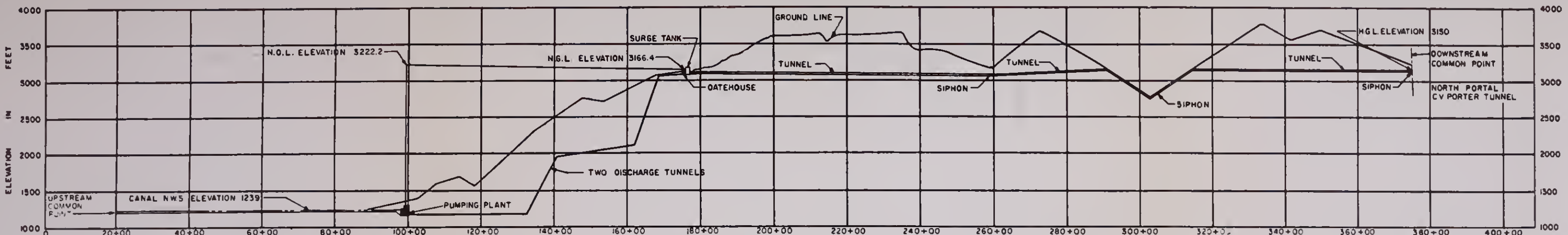
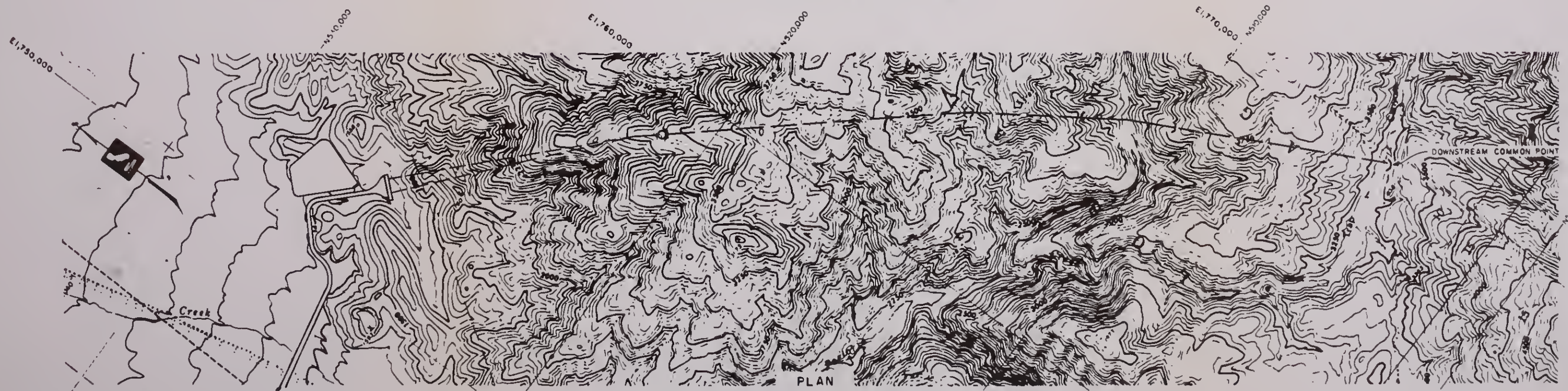
ALTERNATIVE LIFT SYSTEMS

SYSTEM 5
RIDGE SINGLE LIFT WITH UNDERGROUND DISCHARGE LINES
PLAN AND PROFILE

APRIL 1965



PROFILE
HORIZONTAL SCALE OF FEET



PLAN
SCALE OF FEET

GENERAL NOTES

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SYSTEM 5
RIDGE SINGLE LIFT WITH
UNDERGROUND DISCHARGE LINES
PLAN AND PROFILE

APRIL 1965

GENERAL NOTES

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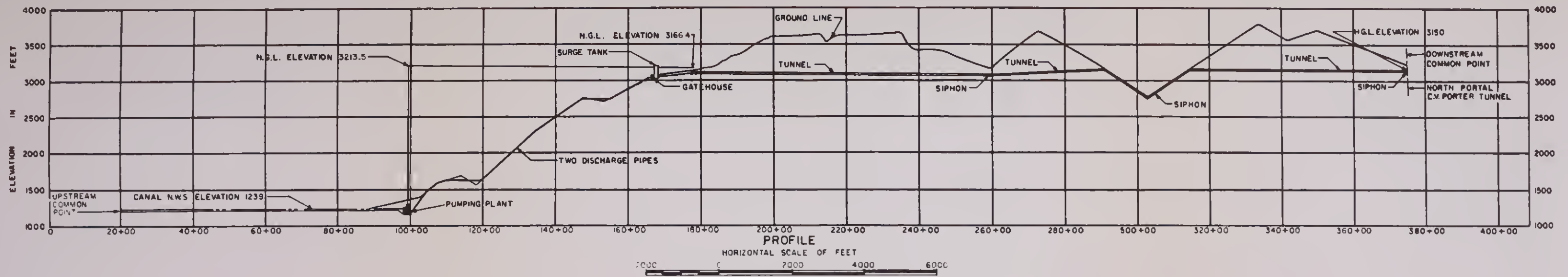
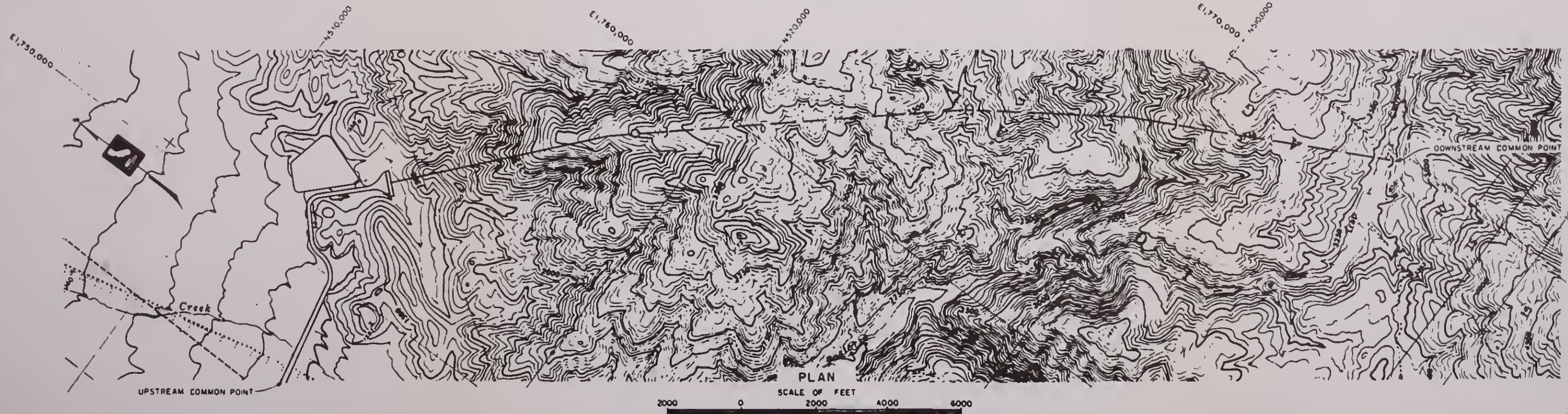
ALTERNATIVE LIFT SYSTEMS

SYSTEM 6
RIDGE SINGLE LIFT WITH
SURFACE DISCHARGE LINES
PLAN AND PROFILE

APRIL 1965





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SYSTEM 6
RIDGE SINGLE LIFT WITH SURFACE DISCHARGE LINES
PLAN AND PROFILE

APRIL 1965

LEGEND

FORMATIONS

CENOZOIC

QUATERNARY – RECENT

Qal — ALLUVIUM: Unconsolidated sand, silt, and gravel.

TERTIARY – MIOCENE

Mv — VOLCANICS: Basalt flows, brecciated flows, and volcanic sediments.

TERTIARY – MIO-OLIGOCENE

M-ϕ — TECUYA FORMATION: Arkosic sandstone and conglomerate. Soft to slightly cemented.

TERTIARY – EOCENE

Et — TEJON FORMATION: Sandstone with minor siltstone and conglomerate. Hard and strong when fresh.

MESOZOIC – JURASSIC?

leqm — LEBEC QUARTZ MONZONITE: Coarse grained, deeply altered and highly fractured.

di — GNEISSIC DIORITE: Banded to foliated; hard and strong when fresh, moderately fractured.

PRE-CAMBRIAN?

ps — PELONA SCHIST: Mica and graphite schist, and quartzite; foliated, sheared and locally crushed.

GARLOCK FAULT ZONE

SYMBOLS

SHEAR ZONE

FAULTS

GEOLOGIC CONTACTS

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ALTERNATIVE LIFT SYSTEMS

GENERALIZED REGIONAL GEOLOGY

APRIL 1968

LEGEND

FORMATIONS

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APRIL 1966

LEGEND

TUNNELING ZONE I		
Rock Condition	Load Factor	Percent of Zone
Massive, moderately jointed; light support and/or rock bolts	0 to 0.25 B	45%
Hard, schistose. Light support and/or rock bolts required.	0 to 0.5 B	45%
Moderately blocky and seamy. Support required. No lateral pressures.	0.35 (B+Ht)	10%

TUNNELING ZONE II		
Rock Condition	Load Factor	Percent of Zone
Moderately blocky and seamy.	0.35 (B+Ht)	45%
Very blocky, seamy.	0.725 (B+Ht)	45%
Completely crushed.	1.1 (B+Ht)	10%

TUNNELING ZONE III		
Rock Condition	Load Factor	Percent of Zone
Completely crushed. Heavy support required.	1.1 (B+Ht)	50%
Very blocky, seamy	0.725 (B+Ht)	50%

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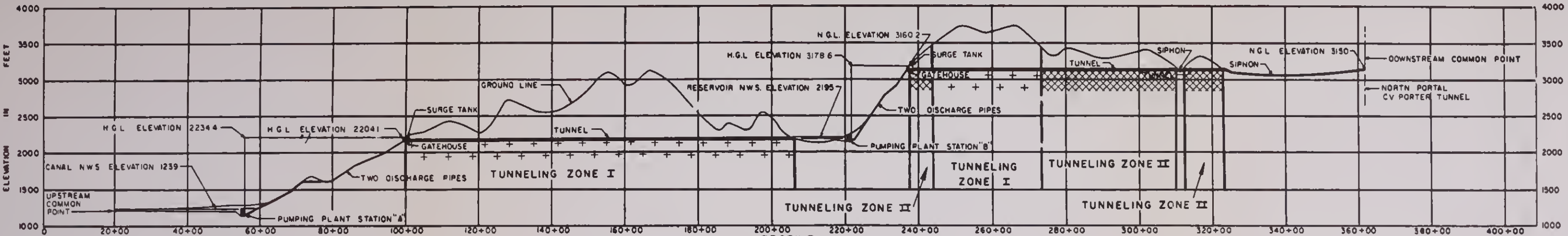
ALTERNATIVE LIFT SYSTEMS

SYSTEM NO. 1
PASTORIA 2-EQUAL LIFT
RELATIVE TUNNELING CONDITIONS
PLAN & PROFILE
APRIL 1965



PROFILE

HORIZONTAL SCALE OF FEET

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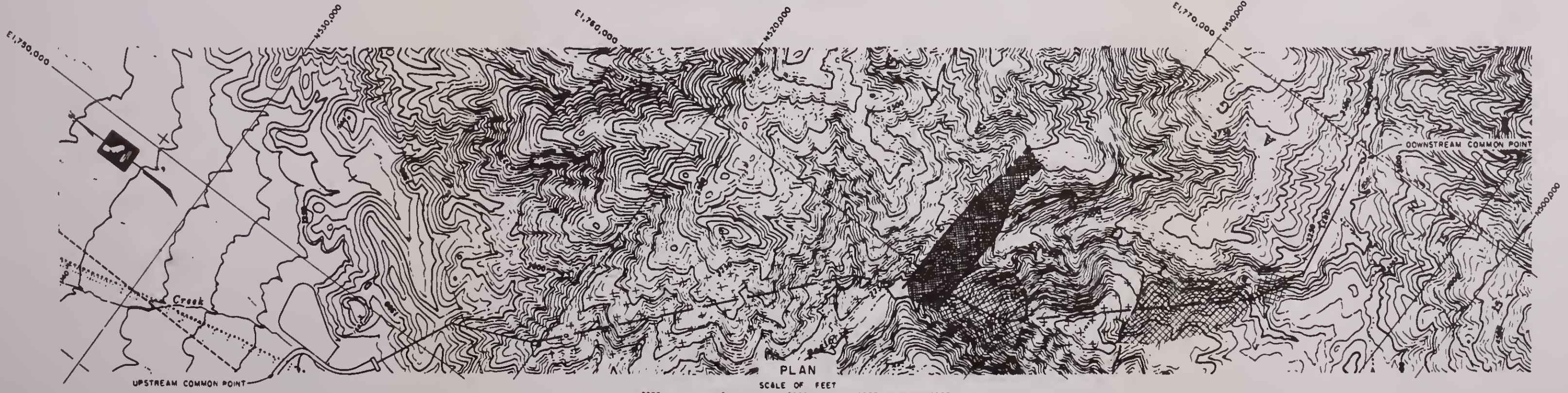

PLAN

SCALE OF FEET

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LEGEND

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RELATIVE TUNNELING CONDITIONS
PLAN & PROFILE

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LEGEND

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TEHACHAPI DIVISION

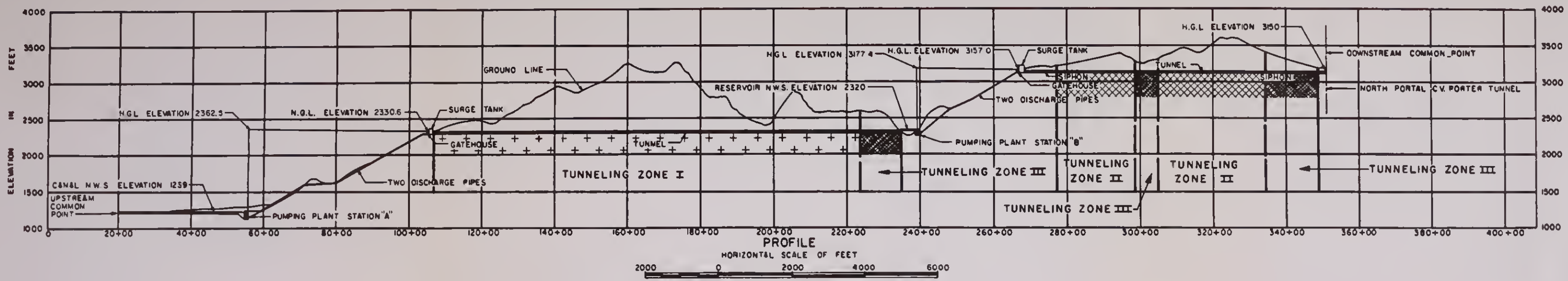
ALTERNATIVE LIFT SYSTEMS

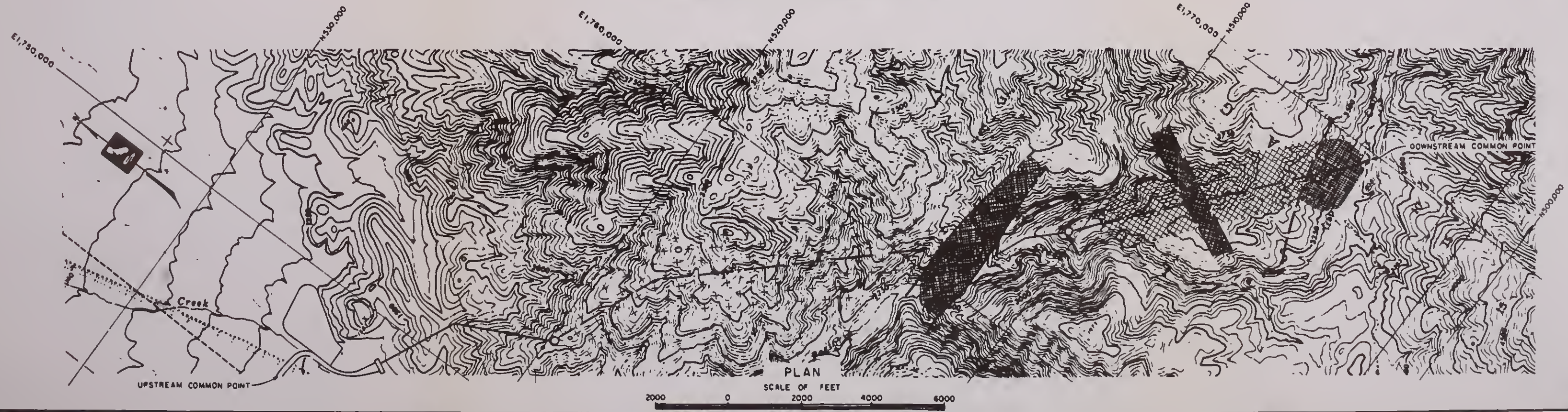
SYSTEM NO. 2

PASTORIA 2 LIFT
RELATIVE TUNNELING CONDITIONS

PLAN & PROFILE

APRIL 1965





LEGEND

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ALTERNATIVE LIFT SYSTEMS

SYSTEM NO. 2
PASTORIA 2 LIFT
RELATIVE TUNNELING CONDITIONS
PLAN & PROFILE
APRIL 1965

LEGEND

TUNNELING ZONE I Rock Condition	Load Factor	Percent of Zone
Massive, moderately jointed; light support and/or rock bolts	0 to 0.25 B	45%
Hard, schistose. Light support and/or rock bolts required.	0 to 0.5 B	45%
Moderately blocky and seamy. Support required. No lateral pressures.	0.35 (B+Ht)	10%

TUNNELING ZONE II Rock Condition	Load Factor	Percent of Zone
Moderately blocky and seamy.	0.35 (B+Ht)	45%
Very blocky, seamy.	0.725 (B+Ht)	45%
Completely crushed.	1.1 (B+Ht)	10%

TUNNELING ZONE III Rock Condition	Load Factor	Percent of Zone
Completely crushed. Heavy support required.	1.1 (B+Ht)	50%
Very blocky, seamy	0.725 (B+Ht)	50%

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT

TEHACHAPI DIVISION

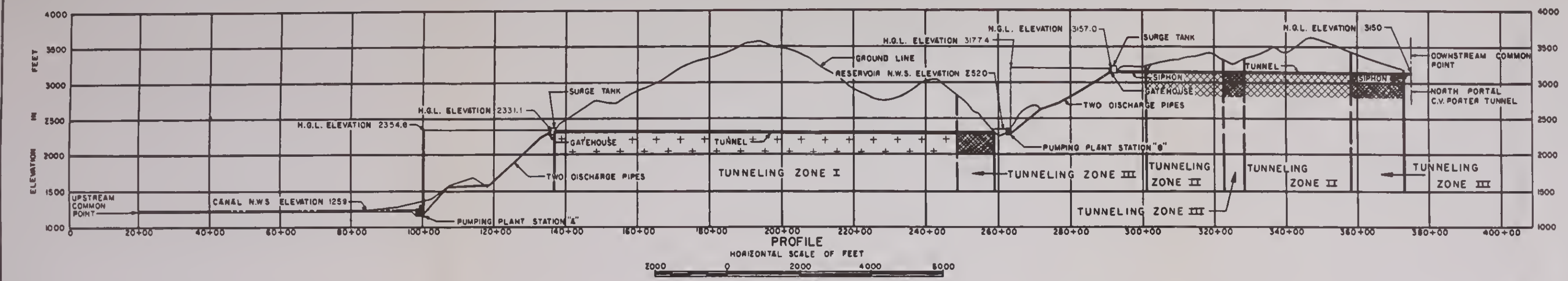
ALTERNATIVE LIFT SYSTEMS

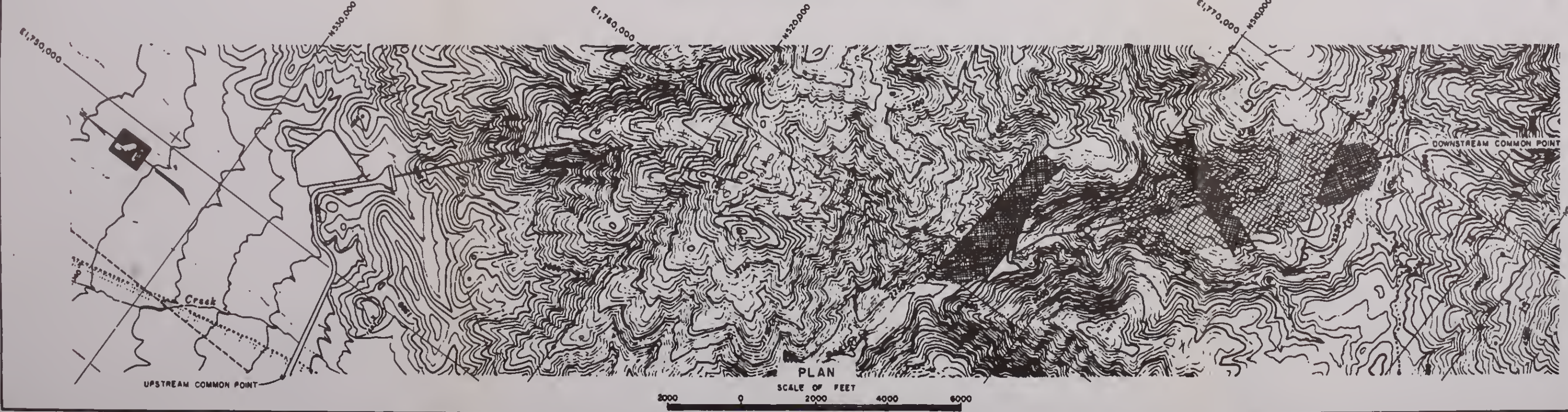
SYSTEM NO. 3

RIDGE-PASTORIA 2 LIFT
RELATIVE TUNNELING CONDITIONS

PLAN & PROFILE

APRIL 1965





LEGEND

Rock Condition	Load Factor	Percent of Zone
TUNNELING ZONE I		
Massive, moderately jointed; light support and/or rock bolts	0 to 0.25 B	45%
Hard, schistose. Light support and/or rock bolts required.	0 to 0.5 B	45%
Moderately blocky and seamy. Support required. No lateral pressures.	0.35 (B+Ht)	10%
TUNNELING ZONE II		
Moderately blocky and seamy	0.35 (B+Ht)	45%
Very blocky, seamy.	0.725 (B+Ht)	45%
Completely crushed.	1.1 (B+Ht)	10%
TUNNELING ZONE III		
Completely crushed. Heavy support required.	1.1 (B+Ht)	50%
Very blocky, seamy	0.725 (B+Ht)	50%

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RELATIVE TUNNELING CONDITIONS
PLAN & PROFILE
APRIL 1960

IMPERVIOUS BORROW AREA

I-1 Slopewash and terrace

I-2 Slopewash and landslide debris

I-3 Residual soil and decomposed rock

I-4 Residual soil and decomposed rock

I-5 Slopewash and terrace

I-6 Slopewash and landslide debris

I-7 Residual soil and decomposed rock

PERVIOUS BORROW AREA

P-1 Alluvium and slopewash

ROCKFILL QUARRY AREA

R-1 Gneissic quartz diorite

NOTE: Exploration and test results are incomplete.

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ALTERNATIVE LIFT SYSTEMS

LOCATION OF POTENTIAL BORROW AREAS

APRIL 1965

IMPERVIOUS BORROW AREA

I-1 Slopewash and terrace

I-2 Slopewash and landslide debris

I-3 Residual soil and decomposed rock

I-4 Residual soil and decomposed rock

I-5 Slopewash and terrace

I-6 Slopewash and landslide debris

I-7 Residual soil and decomposed rock

PERVIOUS BORROW AREA

P-1 Alluvium and slopewash

ROCKFILL QUARRY AREA

R-1 Gneissic quartz diorite

NOTE: Exploration and test results are incomplete.

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LOCATION OF POTENTIAL BORROW AREAS
APRIL 1965